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ECOLOGY OF ATTWATER'S PRAIRIE CHICKEN IN RELATION TO LAND MANAGEMENT PRACTICES ON THE ATTWATER PRAIRIE CHICKEN NATIONAL WILDLIFE REFUGE

Texas A&M University PH.D. 1986

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ECOLOGY OF ATTWATER'S PRAIRIE CHICKEN IN RELATION TO LAND MANAGEMENT PRACTICES ON THE ATTWATER PRAIRIE CHICKEN NATIONAL WILDLIFE REFUGE

A Dissertation

by

MICHAEL EUGENE MORROW

Submitted to the Graduate College of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 1986

Major Subject: Wildlife and Fisheries Sciences

ECOLOGY OF ATTWATER'S PRAIRIE CHICKEN IN RELATION TO LAND MANAGEMENT PRACTICES ON THE ATTWATER PRAIRIE CHICKEN NATIONAL WILDLIFE REFUGE

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December 1986

ABSTRACT

Ecology of Attwater's Prairie Chicken in Relation to Land Management Practices on the Attwater Prairie Chicken National Wildlife Refuge.

(December 1986)

Michael Eugene Morrow, B.S., Kansas State University

M.S., Texas A&M University

Chair of Advisory Committee: Dr. Nova J. Silvy

Radio telemetry equipment was used to collect habitat use, movement and survival data on 49 Attwater's prairie chickens (*Tympanuchus cupido attwateri*) from March 1983-July 1985 on the Attwater Prairie Chicken National Wildlife Refuge.

Annual adult survival was estimated between 10.8%, and 35.5%. Nest success averaged 35% for the 3 years of the study. Survival of entire brood units was estimated at 34% 8 weeks after hatching.

Annual home range size for females averaged 595 ha, while that for males averaged 360 ha. Male movements were greatest during the early booming period, and least during the summer period. Movements by nonreproductive females were reduced during December-February, increased during the March-May nesting season, and then declined during the early summer months. Of 8 relatively extensive moves by females averaging 3.8 km, 5 were to fallow rice fields south of the refuge. Maximum rate of movement for a brood was 176 m/hour by a 1-2-day-old brood. By 7-10 days post-hatching, hens with broods had moved an average 0.7 km away from their nest sites.

Second-year and older burns on loamy grassland areas were

selected with the greatest intensity of all habitat types during winter and spring by males and nonreproductive females. A variety of habitat types were used during summer and fall by these birds. Rank correlations of habitat use with vegetation structural measurements taken from transects, and Chi-square comparisons of mean structural characteristics of habitats used to those available, suggested that quality grassland cover with obstruction of vision values in the 2-dm range were important during the critical winter and nesting periods.

Eighty-five percent of the 26 nests found during the study were in 3rd-year or older burns. Grazing should be regulated so that clumped midgrass in the 2.5-dm range is available for nesting by the 3rd growing season after a burn. Prior to 15 June, broods used grassland stands typified by 2nd-year and older burns on loamy and sandy areas. After 15 June, broods used more open coarse sand and 1st-year burned areas. Habitats that satisfy all requirements for broods should be well interspersed to reduce brood movements. Data on predator abundance indicated no significant changes in abundance during the 3-year study. Consideration of predator control is not recommended until all other recommended habitat improvements have been implemented.

ACKNOWLEDGEMENTS

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Many thanks are due my major professor, Dr. Nova J. Silvy, for his assistance in data collection, for his advice and moral support, and for his friendship. I would also like to thank my committee members, Drs. R. Douglas Slack, Fred E. Smeins, and Wendell G. Swank for their advice during the project and for their critical review of this manuscript.

Many thanks are due to Ginny Brubeck, Ted Doerr, Craig Farquar, Mike Hoy, Karolee Owens, Steve Whipple, and many other students who assisted in data collection or provided "food for thought" during all phases of the project. Special thanks are due Edwin Shanley, Jr. for his friendship and assistance in data collection. Special thanks are also due to the personnel of the Attwater Prairie Chicken National Wildlife Refuge for use of their facilities, and for their help and interest during the project. I am extremely appreciative of Lance Collins and Leigh Robinson for their help during the project.

I would like to thank my parents, Richard and Mary Morrow, for their love and support throughout my educational career. Lastly, and most importantly, I would like to express my deepest appreciation for the love, patience, and support of my wife Kathy, and my two sons Nicholas and Mark. Without their understanding and almost constant sacrifices, my completion of this project would not have been possible.

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INTRODUCTION

The Attwater's prairie chicken (*Tympanuchus cupido attwateri*) is a subspecies of prairie chicken endemic to the coastal prairies along the Gulf of Mexico (Bendire 1894). It shares its subspecies status with the greater prairie chicken (*T. c. pinnatus*) of the northern and central tallgrass prairie, and the now extinct heath hen (*T. c. cupido*) which inhabited grasslands of the east coast. The range of the Attwater's once extended from southwestern Louisiana west and south to the Nueces River in Texas (Lehmann 1968). Historically, populations may have approached 1 million individuals on an estimated 2.4 million ha of available prairie habitat (Lehmann 1968). Beginning in the early 1900's, these numbers began to decline so that by 1937 only approximately 8,700 birds were left on 182,850 ha (Lehmann 1941). The population continued to decline until 1967 when an estimated 1,070 birds were observed (Lehmann 1968). From 1969-85 the population fluctuated between 1,282 (1982) and 2,212 (1971) birds. Loss of prairie habitat has been the primary factor influencing the decline of the Attwater's. These losses have been driven by intensification of agricultural practices within the coastal prairie region, urban and industrial expansion, overgrazing, and invasion of prairie habitat by woody species such as McCartney rose (*Rosa bracteata*), running liveoak (*Quercus virginiana*), huisache (*Acacia farnesiana*), mesquite (*Prosopis glandulosa*), and Chinese tallow (*Sapium sebiferum*) (Lehmann 1941, Jurries 1979, Lawrence and Silvy 1980).

Style and format patterned after *The Journal of Wildlife Management*.

Beginning in 1937, some attention was given the Attwater's in terms of protection and management. The Texas legislature closed the season on this bird in 1937 because of its continued decline. It was classified as threatened with extinction in 1967 under the Endangered Species Preservation Act of 1966. It is currently listed as endangered under the Endangered Species Act of 1973 (U. S. Fish and Wildlife Service 1983). Habitat management for the Attwater's was initiated in the mid-1960's with the purchase of habitat in Colorado County by the World Wildlife Fund and through a private donation of habitat to the Aransas National Wildlife Refuge by Mr. and Mrs. J. M. Tatton. Ownership of the Colorado County habitat was transferred from the World Wildlife Fund to the U. S. Fish and Wildlife Service in 1972. Recent land acquisition has increased the size of this refuge to 3,240 ha (Lawrence and Silvy 1980, U. S. Fish and Wildlife Service 1983). Management programs used on the refuge include burning, mowing, herbicide treatments, controlled grazing, food plots, and construction of drainage ditches (U. S. Fish and Wildlife Service 1983). To date, none of these management practices have been evaluated with specific reference to the ecology of Attwater's prairie chicken except for population censuses conducted by the refuge each spring. These population censuses measure the overall effect of management, but cannot identify positive and negative factors contributing to this overall effect. As a result, this study was proposed to evaluate management practices used for Attwater's prairie chicken, with specific attention given to those employed on the Attwater Prairie Chicken National

Wildlife Refuge. Specific objectives of the study were:

(1) to investigate the effects of continuous grazing distribution patterns on Attwater's prairie chicken habitat,

(2) to investigate the effects of prescribed burning on Attwater's prairie chicken habitat,

(3) to investigate the importance of fallow rice and other cultivated areas to Attwater's prairie chicken ecology, and

(4) to investigate the impact of the these habitat management practices on predator abundance and activity.

(5) to obtain information on the population dynamics of Attwater's prairie chicken.

LITERATURE REVIEW

The 1st detailed study of the general ecology of the Attwater's prairie chicken was conducted by Lehmann (1941). This study documented historical changes in range and population levels, described its general life history, identified habitats used during different stages of the life cycle, and identified factors limiting Attwater's populations. Based upon these findings, Lehmann (1941) recommended management practices for improving Attwater's prairie chicken habitat. In this regard, Lehmann (1941:30) stated that properly managed grassland satisfied every known requirement of the Attwater's. Later work on both the Attwater's and the greater prairie chicken also support this contention (Schwartz 1944,1945; Baker 1953; Hamerstrom et al. 1957; Jones 1963; Lehmann and Mauermann 1963; Chamrad and Dodd 1972; Cogar et al. 1977; Kessler 1978; Horkel 1979; Christisen and Krohn 1980; Horkel and Silvy 1980). According to Lehmann (1941), optimum food and cover conditions exist when a high diversity of species and habitat structure occur in grassland areas.

Jennings (unpubl. rep., Texas Coop. Wildl. Unit, Texas A&M Coll., College Station, 1950), Lehmann and Mauermann (1963), and Lehmann (1968) updated the Attwater's population status. Lehmann and Mauermann also outlined a possible management plan for the Attwater's in Texas. Jennings identified factors limiting Attwater's populations. Lehmann (1965) discussed the historical and current role of fire in the Attwater's range. A later update of the Attwater's population status was provided by Lawrence and Silvy (1980).

Yeatter (1943) presented a detailed monograph on the distribution and life history of greater prairie chickens in Illinois. Yeatter identified moderate grazing, prevention of grassland burning, and use of late harvested hay crops as farming practices that favored prairie chickens. Yeatter (1943) stated that in order for a prairie chicken management program to succeed, public interest and cooperation was essential.

Schwartz (1944,1945) and Baker (1953) conducted in depth studies of greater prairie chicken populations in Missouri and Kansas, respectively. Baker identified the nesting and brood rearing periods as the most critical time periods for greater prairie chickens in eastern Kansas. Both Schwartz and Baker recommended burning and grazing management that would maintain nesting cover.

Hamerstrom et al. (1957) and Hamerstrom and Hamerstrom (1973), worked with the greater prairie chicken in Wisconsin. These investigators indicated that height and density of vegetation and land use practices were more important than the species composition of vegetation in prairie chicken range. The major limiting factor found for Wisconsin prairie chickens, and which these authors felt was the basic problem in all prairie chicken management, was the presence of adequate nesting and brood rearing cover, and winter food.

Jones (1963) stated that it was not enough to recognize that prairie chickens need grasslands. He felt that qualitative differences in grasslands must be recognized and understood relative to prairie chicken management. Jones discussed the characteristics of habitat used by greater prairie chickens in Oklahoma for nesting, brood rearing, roosting, and escape cover.

Arthaud (1968) used radio telemetry to gather data on greater prairie chicken habitat use in Missouri. Arthaud noted that most of the summer requirements of adult males were apparently met by cultivated land, except for roosting cover. However, females required medium-dense stands of grass with some sedges and forbs present for optimum nesting cover.

Cebula (1966), Viers (1967), Briggs (1968), Silvy (1968), and Watt (1969) provided information on the use of radio telemetry in the study of greater prairie chickens, their habitat use, reproductive behavior, home range size, movements, and mortality in Kansas. Movement and habitat utilization data from these studies were summarized in a paper by Robel et al. (1970a). These investigators observed seasonal shifts in mobility, which they attributed to changes in food availability and reproductive behavior. Lehmann (1941) also observed similar shifts in movement patterns of Attwater's populations.

Chamrad and Dodd (1972) studied the effects of prescribed fire and grazing on Attwater's prairie chicken habitat. They concluded that burning strongly influenced the distribution and activity of Attwater's prairie chickens on ungrazed grassland, but not on grazed grassland. In general, these authors stated that burned areas would not have sufficient regrowth by the next season to provide adequate nesting cover. Although prescribed burning increased the quality of nesting and brood cover on all previously unburned areas, these habitats were enhanced most on grazed areas which were deferred throughout, or during the latter half of the postburn growing season. Overall, heights of treated areas were found adequate for prairie chicken cover except for excessively short vegetation on postburn grazed areas. Fall burns were determined to be the most favorable for producing an abundance of vegetative foods.

Westemeier (1972), working with Illinois greater prairie chickens, observed no nests in rank vegetation cover. A general decrease in the use of redtop by nesting prairie chickens was observed after the 2nd or 3rd growing season due to excessive build-up of dead material. Higher nest densities were reported on areas at least 2 years postburn than on unburned plots. Westemeier (1980) reported that data on over 700 nests indicated that hens prefer to nest near some abrupt change in habitat.

Kirsch et al. (1973) and Kirsch (1974) recommended suspending annual mowing and grazing for greater prairie chicken management in the Dakotas. It was obseved that annually grazed, annually burned, or long-term idled areas were undesirable prairie chicken habitat.

Bowman and Robel (1977) conducted a study of juvenile dispersal and mortality in Kansas. Brood mortality for 12 broods averaged 56% during the 1st 10 weeks after hatching. These investigators also estimated juveniles to be twice as vulnerable to predation as adults during early fall.

Drobney and Sparrowe (1977) observed that throughout most of their Missouri range, greater prairie chickens were not associated strictly with a grassland monoculture, but rather with a diverse combination of agricultural practices. Although areas subjected to light-moderate warm season grazing by steers were used more frequently than any other cover type for all activities but feeding in their study, these authors indicated that annual grazing by cow-calf units usually left inadequate residual cover for roosting and nesting.

Cogar et al. (1977) found that Attwater's prairie chickens in Texas used 4 of 8 major vegetation types present on their study area. In addition, artificially maintained areas were extensively used. Clumped and unclumped midgrass contained all nests, and clumped midgrass was the only vegetation type with a preference index indicating selection for the entire year.

Kessler (1978) analyzed 30 variables to determine vegetative responses to burning and mowing of Attwater's prairie chicken range in Texas. No difference was found between species composition or frequency of occurence of major species between treated areas. However, structural differences did exist between treatments including decreased litter cover and biomass, decreased standing dead herbage biomass, increased forb diversity and production, and increased total basal cover on burned areas. Kessler stated that moderate grazing was the most effective tool for maintaining the semi-open grass cover required for winter cover and nesting. In terms of dietary requirements, prairie chickens used forbs with a frequency $>50\%$ in all seasons except fall when peanuts and rice were heavily used. Insect use was seasonal with the greatest use during summer. Native prairie habitat was used heaviest during the cool months, while fallow rice fields were used more during the warm months.

Horkel (1979) and Horkel et al. (1980) using telemetry, confirmed many of the conclusions made by Cogar et al. (1977) from visual observations. Observations on dummy nests by Horkel (1979) indicated no difference in nest predation by cover type. However, nests close to roads or rights-of-way were more susceptible to predation. Seasonal changes in movement patterns were very similar to those reported by Robel et al. (1970a).

Lutz (1979) studied the effects of petroleum development on Attwater's prairie chickens. No difference in mortality or nest success was observed between hens in undeveloped areas and those in areas developed for petroleum production. Horkel and Silvy (1980) discussed the evolutionary consequences of disturbance on the social hierarchy of leks resulting from petroleum development.

Jurries (1979) investigated differences between habitat use and movements of Attwater's prairie chickens in native prairie and ricebelt regions of Texas. In general, ricebelt booming grounds were less stable than those in the native prairie region. Movements and home ranges of birds in the native prairie habitat were consistently greater than those in the ricebelt region. Brood movements appeared to be related to food supply, with broods in the native prairie region moving greater distances than those in the ricebelt, due to wider dispersal of weedy areas in native prairie areas.

Svedarsky (1979) studied the reproductive ecology of greater prairie chickens in Minnesota. Habitats which were undisturbed for more than 1 year with dense, vertically oriented cover at ground level were preferred for nesting. Disturbed habitats accounted for a high proportion of brood locations. High observed brood mortality was attributed to extensive movements, heavy precipitation, lack of favorable brooding areas, and disturbance associated with radio telemetry.

Cogar (1980) investigated the dietary preferences of Attwater's prairie chickens. Adults had a diverse diet with foliar plant parts and seeds from 55 and 9 plant species, respectively, found in prairie chicken droppings. Insects representing 12 families were also identified. Adults consumed 74% foliage, 18% seeds, and 8% insects on an annual basis. Food preferences were twice as numerous for forbs as for grass species.

In a study of food habits of greater prairie chickens on a managed prairie in Missouri, Toney (1980) found that seeds accounted for 57.6% by volume of foods consumed, leafy material 40.7%, and insects 1.3% of the total volume for the year. Wild foods contributed 71% of the volume.

Lawrence (1982) reported an 82% nest success in an area in which small mammalian predators were removed, while a 33% nest success was observed on a control area. However, mortality of radio-tagged hens was greater on the predator reduction area than on the control area.

Buhnerkempe et al. (1984) investigated the effects of residual vegetation on nest placement and success for prairie chickens in Illinois. These authors concluded that nesting habitat should be managed so that 90% of the residual standing vegetation is distributed below 40 cm. However, the vegetation should be dense up to that level. Buhnerkempe et al. further suggested that vegetative structure should be similar among stands to avoid concentration of nest densities in certain areas.

Christisen (1985) documented changes in greater prairie chicken populations and habitat since the mid-1940's in Missouri. Observations indicated that overgrazing, lack of diversity in grasslands, loss of native prairie, and inadequacy of other permanent grass areas in meeting prairie chicken requirements as limiting factors for prairie chicken populations.

Horak (1985) investigated the distribution of greater prairie chickens in Kansas and their use of habitat for various activities in their life cycle. Horak also evaluated survey techniques used for determining prairie chicken population trends in Kansas. Recommendations were given on management techniques beneficial to greater prairie chicken populations.

The recovery plan for the Attwater's prairie chicken (U. S. Fish and Wildlife Service 1983) details management efforts for removing the Attwater's from endangered status. Primary management programs proposed include maintenance of 2 refuges, one of which is the already existing Attwater Prairie Chicken National Wildlife Refuge. A 2nd refuge of similar size is proposed for Goliad or Victoria County in Texas.

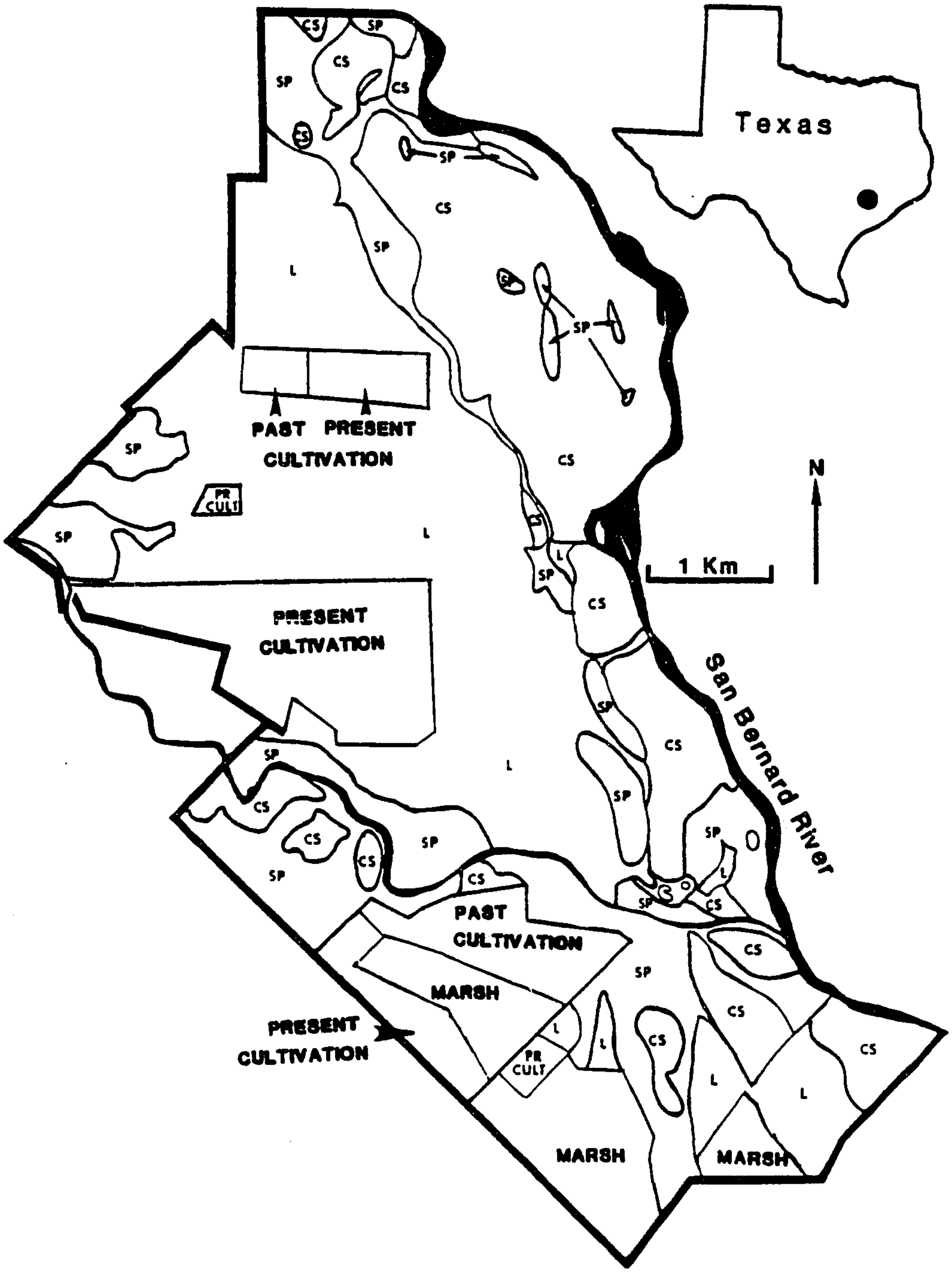
METHODS

Study Area

The 3,240-ha Attwater Prairie Chicken National Wildlife Refuge (APCNWR) located in Colorado County, Texas is composed of 5 major range sites whose soil and vegetation have been described by Kessler (1978). For the purposes of our study, loamy prairie, lowland, and claypan range sites were referred to as loamy sites, sandy prairie sites as sandy, and coarse sand sites as coarse sand (Fig. 1). During the 3 years of the study, which lasted from March 1983-July 1985, management practices used by the refuge for prairie chicken management included prescribed burning, controlled cattle grazing, cultivation of food plots, and rice culture. Prescribed burns were conducted in the 1st 2 years of the study. No burning was conducted in 1985 due to low cover conditions which resulted from low rainfall during 1984. Burns were typically carried out from mid-December to early February, and averaged 60 ha in size during 1983-84. Over the period 1980-84, burn sizes averaged 86 ha. Cattle were grazed in a continuous system at a rate averaging 5.5, 5.3, and 5.7 ha/AU/year, during 1983-85, respectively (APCNWR, unpubl. data). Primary crops planted in food plots included corn, soybeans, and haygrazer sudan. Milo was also planted in 1985. Figure 2 shows the distribution of burned and cultivated areas on APCNWR during 1983-85. Burns older than 5 years were included in the unburned category.

Rainfall for 1983 and 1984 totalled 113.3 and 95.6 cm (APCNWR, unpubl. data), respectively, a departure of +8.0, and -9.7 cm from

Fig. 1. Distribution of major range site groupings on Attwater Prairie Chicken National Wildlife Refuge. L=loamy, SP=sandy, CS=coarse sand, PR CULT=present cultivation.


Texas
N
1 Km
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CULTIVATION
MARSH
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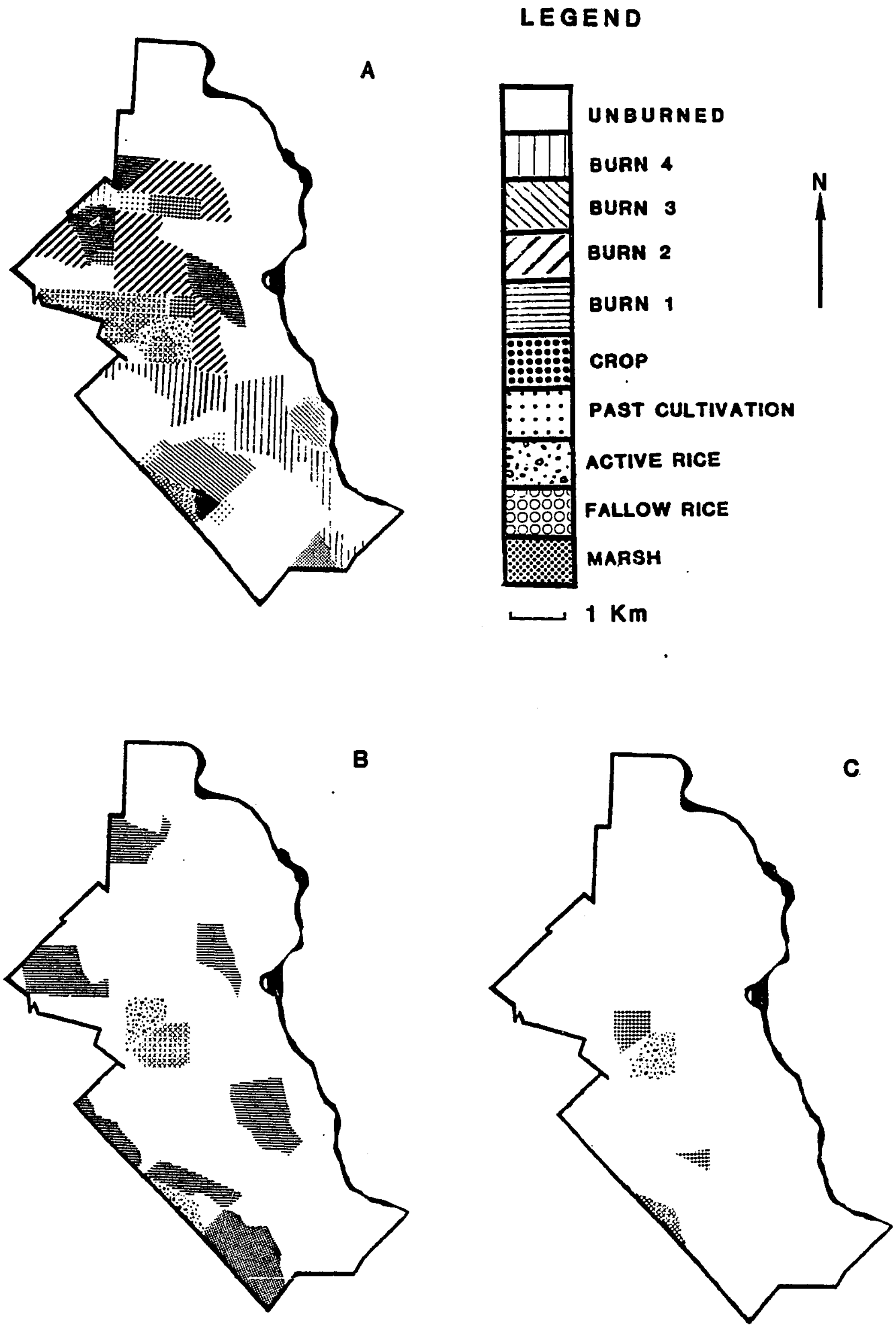
MARSH
MARSH
PR
CULT
CS
SP
L

Fig. 2. (A) Distribution of burns and cultivated areas on Attwater Prairie Chicken National Wildlife Refuge during 1983, and changes in the distribution of these areas in (B) 1984 and (C) 1985.


LEGEND
A
UNBURNED
BURN 4
BURN 3
BURN 2
BURN 1
CROP
PAST CULTIVATION
ACTIVE RICE
FALLOW RICE
MARSH
1 Km
N
B
C

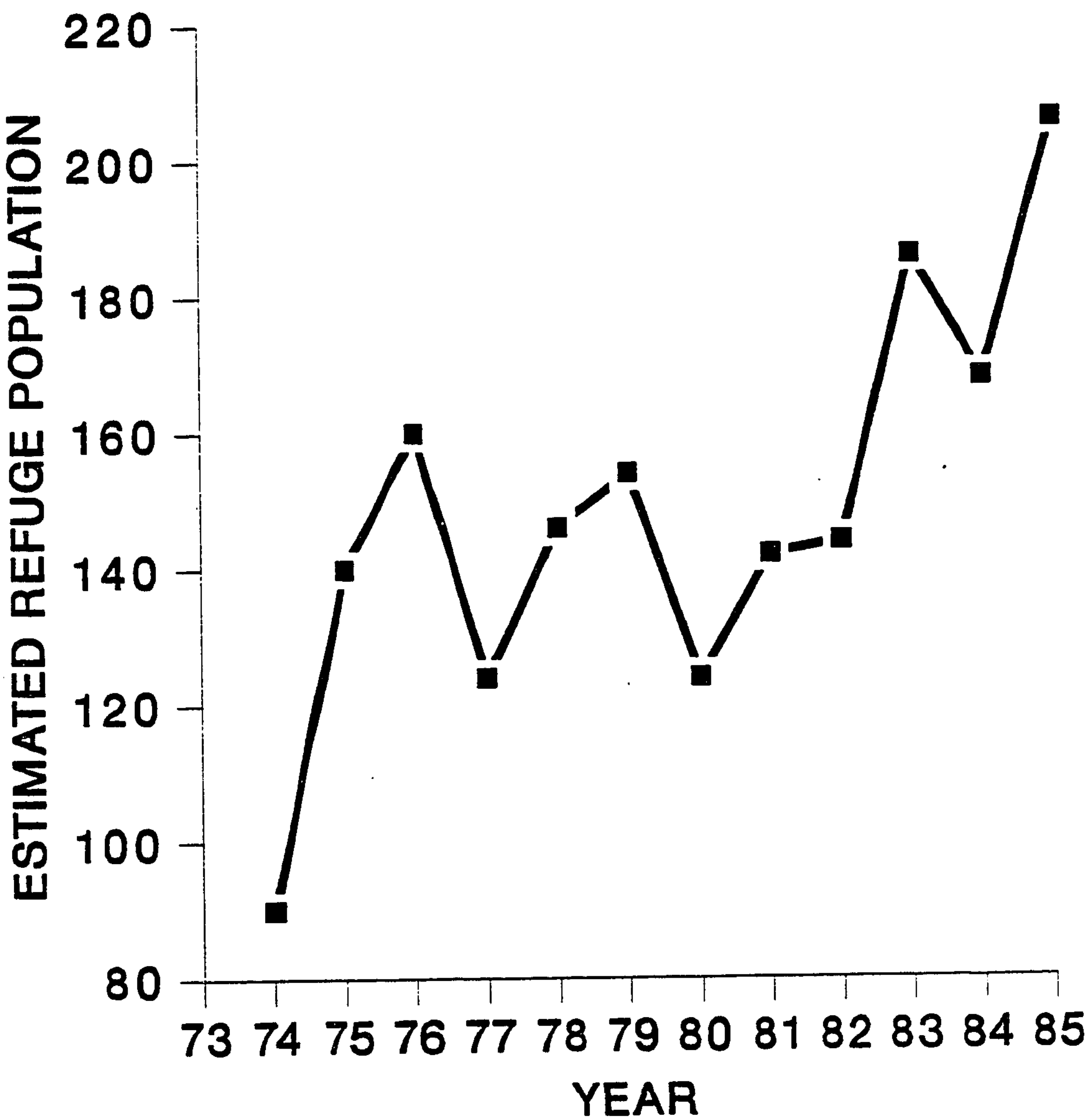
the 82-year average at Columbus, Texas, located 16.1 km west of APCNWR (U.S. Dep. Commerce 1985). Rainfall through September 1985 totalled 71.6 cm, a departure of -9.4 cm from the average. Below average precipitation occurred during the 1st 3 quarters of 1984. Although 20.6 cm above normal precipitation fell during October-December 1984, total rainfall through September of that year was 30.4 cm below the average. During 1985, 7.0 cm above average rainfall occurred during January-March, while 16.4 cm below average rainfall occurred during April-September.

The Attwater's prairie chicken population has been stable to increasing in recent years, climbing from a low of 25 when the refuge was established to the estimated 206 in 1985 (APCNWR, unpubl. data). Complete counts of males have been made continously since 1974 (Fig. 3). Populations for the 1983-85 period were estimated at 186, 168, and 206 individuals, respectively.

Radio Telemetry

Attwater's prairie chickens were captured using helinets (Brown 1981), cannon nets, mist nets (Silvy and Robel 1968), and drop nets (Silvy et al., unpubl. data). Captured birds were equipped with a solar powered transmitter constructed by Wildlife Materials, Inc. (WMI) of Carbondale, Illinois. A limited number of lithium-battery powered radios, also constructed by WMI, were used during 1985. Attachment techniques included a figure-eight harness on the back, and a poncho attachment (Amstrup 1980). Weight of the radio and harness material ranged from 15-23 g, depending upon the type of radio and the attachment

Fig. 3. Population estimates of Attwater's Prairie Chickens on the Attwater Prairie Chicken National Wildlife Refuge (APCNWR, unpubl. data).


ESTIMATED REFUGE POPULATION
220
200
180
160
140
120
100
80
73 74 75 76 77 78 79 80 81 82 83 84 85
YEAR

method used. Although weights of radios attached to individual birds were not recorded, a 23 g radio attached to the lightest female captured (750 g) would correspond to a maximum 3.1% of the body weight. Birds were located at random intervals throughout the day using either a 24 or 36-channel WMI receiver and either a hand-held or vehicle-mounted 3-element yagi antenna. Birds were approached as closely as vehicle access would permit in order to accurately place locations within a habitat treatment-range site group. Locations were plotted on a base map of the area and later assigned to a habitat treatment, range site group, and X-Y coordinate.

Nests were located by following radioed hens to their nest sites only after movements indicated that the hens were incubating in order to lessen the potential for disturbance induced desertion. If a nest failed, an attempt was made to determine the cause of the nest loss by examining sign at the nest site (Darrow 1938, Sooter 1946, Rearden 1951, Stains 1958). Data on brood movements and habitat use were collected by locating those radioed hens which were successful in leaving the nest with a brood. Hens were flushed approximately 6 weeks after leaving the nest to verify presence of chicks.

Vegetation Analyses

In an effort to determine which factors may have been important in habitat selection by Attwater's prairie chickens, 1 vegetation transect was established in each major range site group/habitat treatment complex on the refuge. Each transect, chosen at random from a base map of the refuge, consisted of 15 0.25-m^2 plots placed at 10-m intervals.

Information collected from each plot included obstruction of vision (OV) (Robel et al. 1970b); maximum height of forbs, grasses, standing dead material, and down dead material; estimated coverage classes (Daubenmire 1959) of forbs, grasses, standing dead material, down dead material, and bare ground; and when weather conditions and time permitted, estimated overhead obstruction of vision as determined by use of a light meter. Additionally, seeds and insects were collected on each transect by sweep netting the 1st 20 m of the transect. Seeds and insects were separated, dried to constant weight at 60 C, and weighed on an analytical balance. Data were collected from these transects on a quarterly basis, beginning in July 1983. Due to time constraints, only OV measurements were collected during the 1984 March-May period.

In addition to the vegetation transects, the effects of cattle grazing were determined by placing 3 1.1-m^2 circular grazing exclosures at randomly chosen sites on unburned, 1982 burn, 1983 burn, and 1984 burn loamy, sandy, and coarse sand range site groups when available. These plots were established in June 1984. Data collected at each of the plots were the same as that collected on the vegetation transects. Measurements for each plot were made inside, and at each of the 4 compass points 4 m outside of the plot to assess the impact of grazing on vegetation structure. Data were collected at 6, 9, and 12 month intervals.

Distribution of cattle grazing on habitat treatments was observed on an approximately bi-monthly basis throughout the year, beginning in February 1984. During each cattle observation period, the number of cattle grazing on each habitat treatment along a standardized route covering approximately 2,190 ha of the refuge were counted and plotted on a map of the area.

Predator Abundance and Activity

Weekly spotlight counts of potential predators were conducted on a standardized route located on the refuge. In order to eliminate the effects of changing sightability due to changes in cover density along the route, only those predators sighted in the road were used in later analyses. Predator locations were plotted on a map of the area. Habitat types associated with the predator locations were determined at a later time.

In addition to the spotlight predator counts, an effort was made to identify the cause of death of all radioed birds found dead. In general, if major bones were still intact, avian predation was suspected, while if no major bones were found intact, mammalian predation was suspected (Darrow 1938). However, to minimize the effects of investigator disturbance, radioed birds were not flushed until lack of movements indicated a definite likelihood that the bird was dead. As a result, signs which may have indicated the cause of death were often gone by the time the remains were checked.

Statistical Analyses

Mean daily distances moved by males, females, and broods were determined by calculating the straight-line distance, from X-Y coordinates, between locations made on successive days. If more than 1 observation was made in any 1 day, only 1, selected at random, was used in these analyses. Home range size was determined using the minimum convex polygon method (Mohr 1947). Availability of habitats within individual home ranges was determined using a dot grid acetate overlay. Use of habitats by males and nonreproductive females was compared using the Friedman's method as described by Alldredge and Ratti (1986) with 1 modification. Alldredge and Ratti used the difference between use and availability as the analysis variable. However, this difference did not differentiate between use equal to the availability of the habitat, and use of habitats which were not available in individual home ranges and hence, never used (i.e., zero available, and zero used). To correct this problem, the ratio % use observed/% available + 1 was used. One was added to the percent available to avoid division by zero when availability within the home range was zero. The Friedman's method tests the hypothesis H_{01}: the ratio of use to availability is the same for all habitats. If the Friedman's test resulted in rejection, indicating that some habitats were selected with greater intensity than others, Fisher's least significant difference (LSD) was used to test the hypothesis H_{02}: the ratio between selection and availability for habitat (i) is the same as that for habitat (j) (Aldredge and Ratti 1986). These analyses were conducted lumping all 3 years by quarter, and for the total period lumping years and quarters. Only those birds for which at least 15 locations were obtained in the analysis period were included in the analyses.

Spearman rank correlations (Daniel 1978) of the mean ratio % use/ % available + 1 with mean structural characteristics of a habitat as determined from the vegetation transects, were calculated to provide possible insight into the relationship between habitat structure and habitat use. Rank correlations were also conducted on habitat use with the coefficient of variation for each one of the structural measurements (except insect and seed availability which only had 1 estimate per transect) to assess the relationship between habitat use and cover homogeneity.

The relationship of habitat use with vegetation structure was also approached using Chi-square tests of independence and Bonferroni confidence intervals (Byers et al. 1984). For these analyses, the distribution of the transect mean values for a particular vegetation measurement represented the expected use frequencies, while the actual use was determined by the number of locations within habitats with the various transect mean values. For example, the expected frequency for OV was determined by the proportion of transects with mean OV values of 1, 2, 3, etc. The observed use was then determined by totalling the number of bird locations within observed habitats having a mean OV value of 1, 2, 3, etc.

A Chi-square test of independence (Daniel 1978) was used to test the hypothesis that nesting habitat was selected in proportion to its availability within the composite annual home range of brood hens. Similar analyses with Bonferroni confidence intervals (Byers et al. 1984) were used to test the hypothesis that habitat used for brooding was selected in proportion to its availability. Friedman's method was not used on the brood habitat use data as on the male and nonreproductive female data because of the low number of observations on some of the broods. The Chi-square analysis requires that all observations be lumped, whereas information on individual birds is used in the Friedman's method. Spearman rank correlations and Chi-square analyses with Bonferroni confidence intervals were conducted on the brood habitat use data as for the male and nonreproductive hen data. Mortality for adult birds, excluding those observed for <10 days to avoid possible bias associated with difficulties adjusting to the transmitters, and broods was estimated using Mayfield's method (Johnson 1979).

The difference between the mean outside and the inside vegetation measurements on the grazing exclosure plots were analyzed using Friedman's method (Daniel 1978) in 2 ways. The effect of time on the difference between the ungrazed plot and mean outside measurements was tested by using quarter since establishment as the treatment variable and blocking against habitat type. The effects of habitat type on response of the vegetation to exclusion of cattle grazing was tested using habitat type as the treatment variable and blocking against quarter. In both cases, if the Friedman's detected a difference due to the treatment variable, LSD was used to test for pairwise differences.

Distribution of cattle grazing on habitat types was analyzed by calculating mean effective stocking densities for each habitat type. This value was obtained by dividing the number of AU's counted on a habitat type by the area of that habitat type available. Since cattle locations were only recorded relative to habitat treatment and not range site, habitats were assigned according to the dominant range site grouping for an area. For example, if an area consisted of 75% loamy and 25% sandy sites, the area was assigned to the loamy range site group. These effective stocking density values were then subjected to a Kruskal-Wallis test (Daniel 1978) to test the hypothesis H_0: effective stocking densities were the same for all habitat types (i.e., all habitats were grazed by cattle in proportion to their availability).

Predator census data were summarized by year and quarter. Adjusted percent association with habitat types along the census route for total predators and skunks were calculated by dividing the percent of total observations associated with a habitat type by the availability of that habitat along the census route. Bonferroni 95% confidence intervals (Byers et al. 1984) for individual habitat types were calculated on these adjusted association values. Loamy and sandy range site groups were lumped for this analysis.

Unless otherwise indicated, all differences were considered significant at $\underline{P} \leq 0.05$.

RESULTS

A total of 30 male and 31 female Attwater's prairie chickens was captured during 1983-85 (Appendix A). Forty-three of these were captured with drop nests, 7 with a helinet, 7 with a cannon net, 3 with a mist net, and 2 with a rocket net. Of the 61 birds captured, 30 females and 19 males were equipped with radio transmitters. The figure-eight harness on the back was used on 12 birds, while the poncho-type attachment was used on the remaining 37. Twelve males and 1 female were captured and leg banded only.

Mortality

Radioed birds were located an average 42 times, and were on the air for 111 days on the average. Ten birds which were monitored for <10 days were excluded from habitat use, movement and survival analyses. Average annual survival of radioed birds over the 3-year study was estimated at 10.8%, assuming all birds for which signals were lost were mortalities (Table 1). Considering only those birds found dead, estimated annual survival averaged 35.5% for the 3 years. The actual survival rate experienced by the population during the period was probably somewhere between these 2 estimates, since at least 3 birds were known to have lost their radios during the study, and an additional 3 radios were known to have malfunctioned so that their signal strength was markedly reduced. Another radio used to mark a nest location quit transmitting altogether.

Table 1. Estimated annual survival of radio-equipped Attwater's prairie chickens on the Attwater Prairie Chicken National Wildlife Refuge during 1983-85.

Data	DSR[a]	Survival(%)[b]	95% CI	
			Lower	Upper
All lost birds	0.9939	10.8	4.8	24.1
Found dead only	0.9972	35.5	20.7	62.5

[a]Estimated daily survival rate

[b]Birds surviving less than 10 days after capture were excluded from these analyses

Movements and Home Ranges

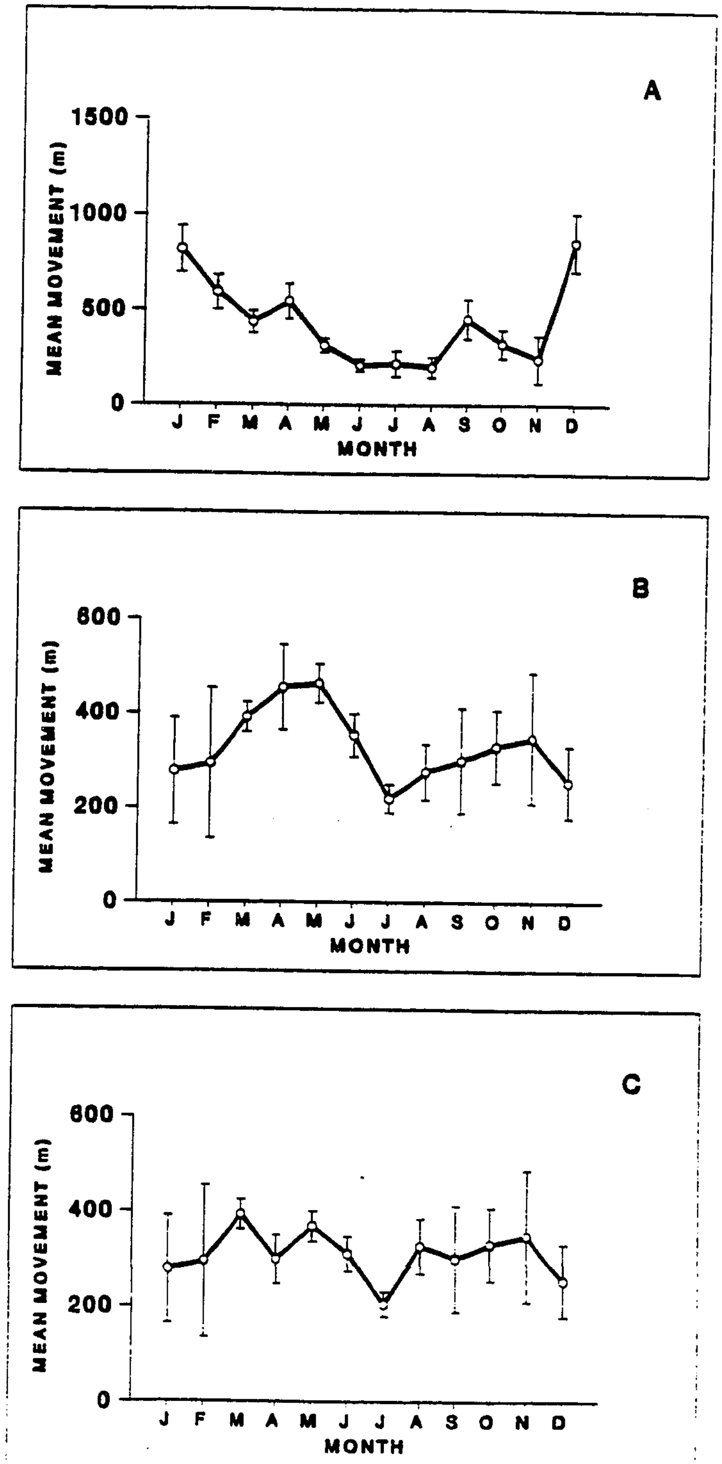
Home range size for females averaged 595 ha (S.E.= ± 91), while male home range size averaged 360 ha (S.E.= ± 55). Mean movement of males between locations on successive days was highest during December at 862 m, and lowest during August at 199 m (Fig. 4A). In general, male movements were greatest during the early booming period (December-February), and steadily declined throughout the booming season, except for April. Summer movements were reduced and fairly consistent, with movements increasing again during the fall period.

Movements of females without nests or broods showed a somewhat different movement pattern, with movements in general being reduced during December-February, and then increasing during March-May, a period corresponding with the nesting season (Fig. 4B). Mean movement for these nonreproductive females declined to a low of 212 m in July before steadily increasing during the late summer to early fall months.

In general, movements of males were greater than those for nonreproductive hens except during the summer when male movements were generally less. Movement patterns of all females including both nesting and brooding hens, showed no definite seasonal variation in movements, with the possible exception of decreased movements in July (Fig. 4C).

Of 8 relatively extensive female movements, averaging 3.8 km, which were observed during this study, 5 were to fallow rice fields south of the refuge. Maximum cumulative movements by females observed were 5.3 and 5.8 km made by 2 females in 1985. Only 2 movements made by males, averaging 3.0 km, were considered relatively extensive during the study. Based on general trends observed in the movement data for males and

Fig. 4. Mean movement of (A) male, (B) nonreproductive female, and (C) all female Attwater's prairie chickens between locations taken on successive days on the Attwater Prairie Chicken National Wildlife Refuge.


A
MEAN MOVEMENT (m)
1500
1000
500
0
J F M A M J J A S O N D
MONTH
B
MEAN MOVEMENT (m)
600
400
200
0
J F M A M J J A S O N D
MONTH
C
MEAN MOVEMENT (m)
600
400
200
0
J F M A M J J A S O N D
MONTH

nonreproductive females in particular, data for subseqent analyses were grouped into quarterly periods with December beginning quarter 1.

Habitat Use

A preliminary analysis on habitat use data for males and females without nests or broods indicated no difference ($\underline{P}$ > 0.05) in selection among 3rd-year or older burned areas within a range site grouping. Thus, these habitats were lumped in order to reduce the number of categories for habitat use analyses.

A comparison of habitats used by males during December-February indicated that 3rd-year and older burns on loamy areas and refuge crops were selected with greater ($\underline{P}$ < 0.05) intensity than all other habitat types except 3rd-year or older burns on sandy areas and 2nd-year burn loamy areas (Table 2). The latter 2 habitat types were not different from 3rd-year plus burns on coarse sand areas. However, these coarse sand burns were not different than all remaining habitats, some of which were not used by any birds. Habitat use data for females were obtained on only 1 bird during quarter 1, precluding use of the Friedman's test. However, a Chi-square test of independence with Bonferroni simultaneous confidence intervals indicated that loamy areas with burns 3 years or older were used more than expected given the availability of these habitat types within this bird's home range.

During the March-May quarter, a period corresponding to the peak nesting and booming periods, both males and females without nests or broods selected 2nd-year and older burns with greater intensity than other habitats within their annual home ranges (Table 3). Substantial

Table 2. Comparison of habitat use within the home ranges of males (M) and nonreproductive females (F) during Dec-Feb 1983-85. Unless otherwise indicated, habitats are burned (B followed by the age of the burn) followed by the range site grouping (L=loamy, S=sandy, CS=coarse sand).

M[a] (<u>N</u> = 3)		F[b] (<u>N</u> = 1)
B3+L	A	
Refuge Crop	A	
B3+S	AB	
B2L	AB	
B3+CS	BC	
B1L	C	
B1S	C	
B2CS	C	
No Crop Cult.	C	
Adjacent Cult.[c]	C	
Adjacent Pasture[c]	C	
Fallow Cultivation	C	
B2Fallow	C	
Fallow Rice	C	
B2S	C	
B1CS	C	
B1 Fallow Cult.	C	

[a]Habitats are listed in descending order of use. Habitats within sex joined by a common letter were not different (P > 0.05) in intensity of selection.

[b]Data collected on only 1 bird during this period, prohibiting analysis with this technique.

[c]Habitats located off the refuge.

Table 3. Comparison of habitat use within the home ranges of males (M) and nonreproductive females (F) during Mar-May 1983-85. Habitats are as indicated in Table 2.

M[a] (N = 9)		F (N = 11)	
B2L	A	B3+L	A
B3+L	A	B2L	A
B3+S	B	B2S	B
B2S	BC	Fallow Rice	B
Refuge Crop	BCD	B3+S	BC
Adjacent Pasture[b]	BCD	B1L	BCD
Fallow Rice	BCD	Fallow Cult.	BCDE
B1S	CD	B3+CS	BCDE
Fallow Cult.	CD	Adjacent Pasture[b]	CDE
B3+CS	CD	Refuge Crop	CDE
B1L	CD	B1S	DE
Adjacent Cult.[b]	D	Adjacent Cult.	E
No Crop Cult.	D	No Crop Cult.	E
B2 Fallow	D	B2 Fallow	E
B2CS	D	B2CS	E
B1CS	D	B1CS	E
B1 Fallow	D	B1 Fallow	E

[a]Habitats are listed in order of descending use. Habitats within sex joined by a common letter were not different ($P > 0.05$) in intensity of selection by the birds

[b]Habitats located off the refuge

overlap was observed in the intensity with which other habitats were selected, with only 2nd-year burned sandy areas for both males and females, 3rd-year and older sandy areas for males, and fallow rice and 1st-year loamy burns for females being different ($\underline{P} < 0.05$) than the group of habitats with the lowest selection intensity, some of which were never used by either group.

Use of habitats during June-August for both males and nonreproductive females was again characterized by a high degree of overlap with respect to the intensity with which these habitats were selected (Table 4). Males clearly selected 2nd-year burned loamy areas ($\underline{P} < 0.05$) with greater intensity than all other habitats, while fallow rice and refuge crops were selected with greater intensity than the lowest ranked group, again some of which were never used. Hens without nests or broods during this period used 3rd-year or older burns on coarse sand areas more than all other habitats, although not significantly so from 2nd-year and older burned loamy areas, 3rd-year plus sandy areas, fallow rice, and pastures adjacent to the refuge. However, 3rd-year and older sandy areas and adjacent pastures were also grouped with habitats with the lowest selection intensities, as indicated by the Friedman's/LSD procedures.

During September-November, the last quarter of the analysis year, males selected 3rd-year plus burns with the greatest intensity, although not significantly more ($\underline{P} > 0.05$) than 2nd-year burn loamy areas, fallow rice, refuge crops, or fallow cultivation (Table 5). Of all the habitats used by males during this quarter, only the 2 habitat categories consisting of burns 2+ years old were used more than habitats

Table 4. Comparison of habitat use within the home ranges of males (M) and nonreproductive females (F) during Jun-Aug 1983-85. Habitats are as indicated in Table 2.

M[a] (N = 7)		F (N = 8)	
B2L	A	B3+CS	A
Fallow Rice	B	B3+L	AB
Refuge Crop	BC	Fallow Rice	AB
B3+L	BCD	B2L	AB
B2CS	BCD	B3+S	ABC
B3+S	BCD	Adjacent Pasture[b]	ABC
B3+CS	CD	B2CS	BC
B1L	D	Refuge Crop	BC
No Crop Cult.	D	B2S	BC
Adjacent Cult.[b]	D	B1S	BC
Fallow Cult.	D	B1L	C
B2 Fallow	D	Adjacent Cult.[b]	C
Adjacent Pasture[b]	D	B2 Fallow	C
B2S	D	Fallow Cult.	C
B1CS	D	B1CS	C
B1 Fallow	D	B1 Fallow	C

[a]Habitats are listed in order of descending use. Habitats within sex joined by common letter were not different ($P > 0.05$) in intensity of selection.

[b]Habitats located off the refuge.

Table 5. Comparison of habitat use within the home ranges of males (M) and nonreproductive females (F) during Sep-Nov 1983-85. Habitats are as indicated in Table 2.

M[a] ($\underline{N}$ = 3)		F ($\underline{N}$ = 2)	
B3+L	A	Fallow Rice	A
B2L	AB	B1L	AB
Fallow Rice	ABC	B3+S	AB
Refuge Crop	ABC	B3+L	AB
Fallow Cultivation	ABC	B2L	AB
B1 Fallow	BC	B2CS	AB
B1L	C	B3+CS	BC
B1S	C	B2 Fallow	C
No Crop Cult.	C	B1S	C
Adjacent Cult.[b]	C	No Crop Cult.	C
B2S	C	Adjacent Cult.[b]	C
B2CS	C	Fallow Cult.	C
B2 Cult.	C	Refuge Crop	C
Adjacent Pasture[b]	C	Adjacent Pasture[b]	C
B3+CS	C	B2S	C
B1CS	C	B1CS	C
B3+S	C	B1 Fallow	C

[a]Habitats are listed in order of descending use. Habitats within sex joined by a common letter are not different ($\underline{P}$ > 0.05) in intensity of selection by the birds.

[b]Habitats located off the refuge.

in the lowest ranked group of habitats, again some of which were not used at all. The females observed during this quarter used fallow rice the most, although not significantly more than any of the loamy burn categories, sandy burns older than 3 years, or 2nd-year coarse sand burns. None of these habitats except fallow rice was different than coarse sand burns older than 3 years, which were not different with respect to intensity of selection by females than the lowest ranked group of habitats.

Over the entire December-November period, considerable overlap in habitat use groupings were indicated by the LSD procedure (Table 6). Males used 2nd-year loamy burns the most, although not significantly more ($\underline{P} > 0.05$) than loamy burns 3 years or older and fallow rice. These habitats, along with sandy burns 2 years or older and refuge crops were all selected with greater intensity than the lowest ranked group, which contained habitats that were not used by any birds. Nonreproductive females selected loamy burns 2 years or older most, although not significantly greater than sandy burns 3 years and older. Including these habitats, females without nests or broods also selected fallow rice, 3rd-year and older coarse sand burns, 2nd-year sandy burns, and 1st-year loamy burns with greater intensity than the least used group of habitats (Table 6).

Spearman rank correlations of habitat use adjusted for habitat availability, with vegetation stuctural characteristics and insect and seed availabilty for males during December-February, revealed significant ($\underline{P} < 0.05$) correlations for maximum height of down dead material ($\underline{r} = 0.81$) (Table 7). For females, significant correlations

Table 6. Comparison of habitat use within the home ranges of males (M) and nonreproductive females (F) during 1983-85. Habitats are as indicated in Table 2.

M[a] (N = 10)		F (N = 15)	
B2L	A	B3+L	A
B3+L	AB	B2L	AB
Fallow Rice	ABC	B3+S	BC
B3+S	BCD	Fallow Rice	CD
Refuge Crop	CDE	B3+CS	CD
B2S	CDEF	B2S	CDE
Adjacent Pasture[b]	DEF	B1L	DEF
Fallow Cult.	EF	Adjacent Pasture[b]	DEFG
B3+CS	EF	Fallow Cult.	DEFG
B2CS	EF	B1S	EFG
B1L	EF	Refuge Crop	EFG
B1S	EF	B2CS	FG
B1 Fallow	EF	Adjacent Cult.[b]	G
B2 Fallow	F	B2 Fallow	G
No Crop Cult.	F	No Crop Cult.	G
B1CS	F	B1CS	G
Adjacent Cult.[b]	F	B1 Fallow	G

[a]Habitats are listed in order of descending use. Habitats within sex joined by a common letter are not different ($P > 0.05$) in intensity of selection by the birds.

[b]Habitats located off the refuge.

Table 7. Results of simple rank correlations of mean habitat use for males (M) and nonreproductive females (F) adjusted to common availabilities, with mean structural measurements on vegetation transects during Dec-Feb, 1983-85. MFHT = maximum forb height, MGHT = maximum grass height, MSDMHT = maximum standing dead matter height, MDDMHT = maximum down dead matter height, FCC=forb canopy cover, GCC=grass canopy cover, SDMCC=standing dead matter canopy cover, DDMCC = down dead matter canopy cover, GRNDCC = bare ground canopy cover, COB = canopy obstruction, CV = coefficient of variation.

	M		F		MF	
Measurement	*r*	*P*	*r*	*P*	*r*	*P*
OV	0.70	0.12	0.70	0.12	**0.67**	0.02
MFHT	-0.70	0.12	-0.39	0.44	-0.56	0.06
MGHT	0.52	0.29	0.70	0.12	**0.58**	0.05
MSDMHT	0.43	0.39	0.70	0.12	0.54	0.07
MDDMHT	**0.81**	0.05	**0.88**	0.02	**0.83**	0.001
FCC	-0.14	0.78	-0.39	0.43	-0.26	0.41
GCC	0.03	0.96	-0.34	0.51	-0.21	0.52
SDMCC	0.70	0.12	0.70	0.12	**0.67**	0.02
DDMCC	0.49	0.32	0.52	0.29	0.47	0.12
GRNDCC	-0.43	0.39	-0.70	0.12	-0.54	0.07
COB	0.70	0.12	0.70	0.12	0.67	0.02
INSECTS	-0.75	0.08	**-0.94**	0.006	**-0.88**	0.0002
SEEDS	-0.41	0.42	-0.39	0.44	-0.44	0.15
CV OV	0.46	0.35	0.33	0.52	0.43	0.15
CV MFHT	0.17	0.74	-0.15	0.77	-0.05	0.86
CV MGHT	0.41	0.42	0.03	0.95	0.17	0.58
CV SDMHT	-0.11	0.83	-0.33	0.52	-0.21	0.49
CV DDMHT	-0.32	0.54	-0.39	0.44	-0.35	0.26
CV FCC	-0.20	0.70	-0.03	0.95	-0.15	0.65
CV GCC	0.41	0.42	0.33	0.52	0.29	0.36
CV SDMCC	-0.03	0.96	-0.51	0.29	-0.35	0.26
CV DDMCC	-0.41	0.42	-0.21	0.69	-0.22	0.49
CV GRNDCC	0.72	0.10	**0.88**	0.02	**0.79**	0.01
CV COB	-0.41	0.42	-0.51	0.29	-0.43	0.17

were detected for maximum down dead material ($\underline{r}$ = 0.88), insect availability (r = -0.94), and the coefficient of variation for bare ground canopy cover. Combining male and female data for quarter 1, significant correlations were observed for OV ($\underline{r}$ = 0.67), maximum grass height ($\underline{r}$ = 0.58), maximum down dead matter height ($\underline{r}$ = 0.83), insect availability ($\underline{r}$ = -0.88), and bare ground cover coefficient of variation ($\underline{r}$ = 0.79). In addition, insect availabilty ($\underline{r}$ = -0.75) and bare ground coefficient of variation ($\underline{r}$ = 0.72) for males, and maximum forb height ($\underline{r}$ = -0.56), maximum height of standing dead material ($\underline{r}$ = 0.54), and bare ground coverage ($\underline{r}$ = -0.54) for males and females combined, were significantly correlated with habitat use adjusted for availability at $\underline{P} \leq 0.10$.

During March-May, male habitat use adjusted for availability was significantly ($\underline{P}$ < 0.05) correlated with maximum forb height ($\underline{r}$ = 0.94) and seed availability ($\underline{r}$ = -0.83) (Table 8). Use of habitat by females without nests or broods during this period was correlated with maximum grass height ($\underline{r}$ = 0.94), grass coverage ($\underline{r}$ = 0.83), and down dead material coverage coefficient of variation ($\underline{r}$ = -0.89). For both males and females combined, significant correlations were observed for maximum forb height ($\underline{r}$ = 0.66), maximum grass height ($\underline{r}$ = 0.86), grass coverage ($\underline{r}$ = 0.68), grass coverage coefficient of variation ($\underline{r}$ = -0.65), and down dead material coverage coefficient of variation ($\underline{r}$ = -0.59). Maximum grass height ($\underline{r}$ = 0.77) for males, and seed availabilty ($\underline{r}$ = -0.49) and bare ground coverage coefficient of variation for males and females combined were significant at $\underline{P} \leq 0.10$.

For the summer months of June-August, male and nonreproductive

Table 8. Results of simple rank correlations of mean habitat use for males (M) and nonreproductive females (F) adjusted to common availabilities, with mean structural measurements on vegetation transects during Mar-May 1983-85. Vegetation measurements are as indicated in Table 7.

Measurement	M		F		MF	
	r	P	r	P	r	P
OV	0.66	0.16	0.26	0.62	0.40	0.20
MFHT	**0.94**	0.01	0.49	0.33	**0.66**	0.02
MGHT	0.77	0.07	**0.94**	0.01	**0.86**	0.001
MSDMHT	0.26	0.62	0.54	0.27	0.41	0.19
MDDMHT	-0.03	0.96	0.37	0.47	0.18	0.57
FCC	0.20	0.70	-0.03	0.96	0.11	0.73
GCC	0.60	0.21	**0.83**	0.05	**0.68**	0.02
SDMCC	0.09	0.87	0.60	0.21	0.33	0.30
DDMCC	-0.09	0.87	-0.03	0.96	-0.08	0.79
GRNDCC	-0.37	0.47	-0.49	0.33	-0.41	0.19
COB	0.40	0.60	0.60	0.40	0.49	0.22
INSECTS	-0.37	0.47	0.20	0.70	-0.07	0.83
SEEDS	**-0.83**	0.04	-0.26	0.62	-0.49	0.10
CV OV	-0.37	0.47	-0.26	0.62	-0.30	0.35
CV MFHT	-0.09	0.87	-0.20	0.70	-0.13	0.69
CV MGHT	-0.03	0.96	-0.02	0.96	-0.01	0.97
CV MSDMHT	-0.26	0.62	-0.43	0.40	-0.40	0.20
CV MDDMHT	0.03	0.96	-0.54	0.27	-0.31	0.33
CV FCC	-0.31	0.54	-0.43	0.40	-0.38	0.22
CV GCC	-0.54	0.27	-0.71	0.11	**-0.65**	0.03
CV SDMCC	-0.20	0.70	-0.60	0.21	-0.43	0.15
CV DDMCC	-0.26	0.62	**-0.89**	0.02	**-0.59**	0.05
CV GRNDCC	-0.37	0.47	-0.66	0.16	-0.54	0.07
CV COB	-0.40	0.60	-0.60	0.40	-0.49	0.22

female habitat use was correlated ($\underline{P}$ < 0.05) with maximum standing dead matter height coefficient of variation ($\underline{r}$ = -0.98), while female habitat use was also correlated with insect availability ($\underline{r}$ = -0.81) (Table 9). For males and females combined, OV ($\underline{r}$ = 0.49), maximum standing dead matter height ($\underline{r}$ = 0.50), maximum standing dead matter coefficient of variation ($\underline{r}$ = -0.90), and insect availability ($\underline{r}$ = 0.63) were correlated with habitat use. Down dead material coverage was also correlated with male and female combined habitat use ($\underline{r}$ = 0.48) at $\underline{P}$ < 0.10.

During the fall months of September-November, no significant correlations of habitat use with vegetation characteristics were observed at $\underline{P}$ < 0.05 for males, although correlations with maximum forb height coefficient of variation ($\underline{r}$ = -0.68) were significant at $\underline{P}$ < 0.10 (Table 10). Female habitat use during this period was correlated with maximum forb height ($\underline{r}$ = 0.79) and insect availability ($\underline{r}$ = 0.71). Only correlations with insect availability ($\underline{r}$ = 0.53) were significant for the combined male and female habitat use during this period.

Over the entire year from December-November, male habitat use was correlated ($\underline{P}$ < 0.05) with grass canopy coverage ($\underline{r}$ = -0.41), down dead material ($\underline{r}$ = 0.44), and seed availability ($\underline{r}$ = -0.44) (Table 11). Forb canopy coverage coefficient of variation ($\underline{r}$ = -0.32) was also significant at $\underline{P}$ < 0.10. No significant correlations were observed for non-reproductive females at $\underline{P}$ < 0.05, although that for maximum down dead material height ($\underline{r}$ = 0.33) was significant at $\underline{P}$ = 0.10. For the male and female data combined, significant correlations of yearly habitat use with grass canopy coverage ($\underline{r}$ = -0.41), down dead material

Table 9. Results of simple rank correlations of mean habitat use for males (M) and nonreproductive females (F) adjusted to common availabilities, with mean structural measurements on vegetation transects during Jun-Aug 1983-85. Vegetation measurements are as indicated in Table 7.

	M		F		MF	
Measurement	*r*	*P*	*r*	*P*	*r*	*P*
OV	0.61	0.11	0.33	0.42	**0.49**	0.05
MFHT	0.32	0.44	0.19	0.65	0.26	0.33
MGHT	-0.02	0.95	-0.12	0.78	-0.07	0.81
MSDMHT	0.61	0.11	0.40	0.32	**0.50**	0.05
MDDMHT	0.27	0.56	-0.04	0.94	0.13	0.66
FCC	0.49	0.22	0.21	0.61	0.38	0.15
GCC	-0.32	0.44	-0.52	0.18	-0.42	0.11
SDMCC	0.34	0.41	0.21	0.61	0.27	0.31
DDMCC	0.49	0.22	0.52	0.18	0.48	0.06
GRNDCC	-0.32	0.44	-0.12	0.78	-0.22	0.41
COB	0.15	0.73	-0.05	0.91	0.07	0.79
INSECTS	0.56	0.15	**0.81**	0.02	**0.63**	0.01
SEEDS	0.07	0.86	-0.05	0.91	0.01	0.96
CV OV	-0.44	0.28	-0.02	0.96	-0.27	0.32
CV MFHT	-0.46	0.25	-0.04	0.91	-0.32	0.22
CV MGHT	-0.05	0.91	0.33	0.42	0.09	0.74
CV MSDMHT	**-0.98**	0.0001	**-0.81**	0.02	**-0.90**	0.0001
CV MDDMHT	-0.11	0.82	-0.21	0.64	-0.13	0.65
CV FCC	-0.34	0.41	-0.02	0.96	-0.23	0.39
CV GCC	0.10	0.82	0.33	0.42	0.17	0.52
CV SDMCC	-0.44	0.28	-0.24	0.57	0.34	0.20
CV DDMCC	-0.40	0.38	-0.43	0.34	-0.36	0.20
CV GRNDCC	0.41	0.31	0.19	0.65	0.32	0.23
CV COB	-0.24	0.56	0.14	0.74	-0.08	0.77

Table 10. Results of simple rank correlations of mean habitat use for males (M) and nonreproductive females (F) adjusted to common availabilities, with mean structural measurements on vegetation transects during Sep-Nov 1983-85. Vegetation measurements are as indicated in Table 7.

Measurement	M		F		MF	
	r	P	r	P	r	P
OV	0.22	0.60	0.16	0.71	0.17	0.52
MFHT	0.00	1.00	**0.79**	0.02	0.35	0.19
MGHT	-0.03	0.95	-0.11	0.80	-0.07	0.80
MSDMHT	0.16	0.70	-0.07	0.87	0.05	0.86
MDDMHT	0.08	0.85	0.17	0.69	0.12	0.67
FCC	0.33	0.43	0.56	0.15	0.42	0.11
GCC	-0.25	0.56	-0.16	0.71	-0.20	0.45
SDMCC	-0.21	0.62	0.16	0.71	-0.03	0.92
DDMCC	0.14	0.75	-0.01	0.98	0.06	0.84
GRNDCC	-0.08	0.85	0.10	0.81	0.02	0.95
COB	0.11	0.80	-0.05	0.91	0.02	0.93
INSECTS	0.46	0.24	**0.71**	0.05	**0.53**	0.04
SEEDS	-0.35	0.39	0.01	0.98	-0.18	0.51
CV OV	-0.11	0.80	-0.05	0.91	-0.07	0.79
CV MFHT	-0.68	0.06	-0.02	0.96	-0.34	0.20
CV MGHT	0.27	0.51	0.28	0.51	0.28	0.29
CV MSDMHT	-0.33	0.46	0.57	0.18	0.10	0.73
CV MDDMHT	0.16	0.70	0.50	0.20	0.33	0.21
CV FCC	-0.41	0.31	-0.07	0.87	-0.23	0.39
CV GCC	-0.03	0.95	0.61	0.11	0.25	0.34
CV SDMCC	0.19	0.65	-0.01	0.98	0.09	0.73
CV DDMCC	0.38	0.35	-0.04	0.93	0.19	0.49
CV GRNDCC	-0.46	0.25	-0.04	0.93	-0.27	0.32
CV COB	-0.52	0.19	-0.16	0.71	-0.32	0.23

Table 11. Results of simple rank correlations of mean habitat use for males (M) and nonreproductive females (F) adjusted to common availabilities, with mean structural measurements on vegetation transects during Dec-Nov 1983-85. Vegetation measurements are as indicated in Table 7.

Measurement	M		F		MF	
	r	P	r	P	r	P
OV	0.02	0.90	0.19	0.34	0.02	0.90
MFHT	-0.28	0.15	0.04	0.83	-0.28	0.15
MGHT	-0.22	0.24	0.06	0.75	-0.23	0.24
MSDMHT	0.10	0.60	0.09	0.66	0.10	0.60
MDDMHT	0.26	0.19	0.33	0.10	0.26	0.19
FCC	0.29	0.13	0.28	0.16	0.29	0.13
GCC	**-0.41**	0.04	-0.23	0.24	**-0.41**	0.03
SDMCC	0.23	0.23	0.16	0.41	0.23	0.23
DDMCC	**0.44**	0.03	0.31	0.11	**0.44**	0.02
GRNDCC	-0.13	0.51	-0.11	0.56	-0.13	0.51
COB	-0.04	0.86	0.07	0.73	-0.04	0.86
INSECTS	-0.17	0.38	0.09	0.66	-0.06	0.65
SEEDS	**-0.44**	0.02	-0.17	0.40	**-0.31**	0.02
CV OV	0.19	0.33	0.13	0.51	0.19	0.33
CV MFHT	-0.23	-0.23	-0.13	0.50	-0.23	0.23
CV MGHT	0.12	0.56	0.04	0.84	0.12	0.56
CV MSDMHT	-0.17	0.40	-0.11	0.58	-0.17	0.40
CV MDDMHT	-0.18	0.38	-0.13	0.52	-0.18	0.38
CV FCC	-0.32	0.09	-0.28	0.15	-0.32	0.09
CV GCC	-0.03	0.87	0.05	0.79	-0.03	0.87
CV SDMCC	-0.14	0.47	-0.28	0.17	-0.14	0.47
CV DDMCC	-0.20	0.32	-0.27	0.17	-0.20	0.32
CV GRNDCC	0.05	0.82	0.03	0.87	0.05	0.82
CV COB	0.05	0.82	-0.05	0.80	0.05	0.82

coverage (r = 0.44), and seed availability (r = -0.31) were observed. In addition, the correlation for forb canopy cover coefficient of variation (r = -0.32) was significant at $P < 0.10$.

With respect to structural characteristics of habitat used by male and nonreproductive female Attwater's prairie chickens during the study, results of the Chi-square tests of independence coupled with Bonferroni confidence intervals are presented in Table 12. In general, habitats with OV values in the lowest range were used less than expected, while habitats with mean OV values in the range of 2 dm were generally selected more than expected throughout the year. Denser habitat, when available, was used less than expected except during the September-November period when habitat with OV values averaging 3.5 dm was used more than expected. Across the year, OV values in the 1 and 2-dm range were used more than expected, while those in the 0.5, 1.5, and >2.5-dm ranges were used less than expected.

Use of habitats with maximum forb heights less than 60 cm were generally used more than expected or in proportion to their availability, except for vegetation with maximum forb heights averaging 20 cm, which were generally used less than expected when available (Table 12). Over the entire year, habitats with mean maximum forb heights in the 20 and 60-70 cm ranges were used less than expected, while those in the 30-50 cm range were either used more than expected or in proportion to their availability.

Habitats with mean maximum grass heights in the highest available range were use more ($P < 0.05$) than expected for all quarters during the year (Table 12). In September-November, maximum grass heights in the

Table 12. Comparison of use and availability of mean structural characteristics of habitats for males and nonreproductive females during 1983-85. A + = greater than expected use, a - = less than expected, 0 = no difference ($P > 0.05$) between use and availability, NA = not available, L = classes lumped with classes above for Chi-square analyses. Vegetation measurements are as indicated in Table 7.

Measurement class	Dec-Feb	Mar-May[a]	Jun-Aug	Sep-Nov	Total
OV(0.5 dm)					
1	-	-	-	NA	-
2	0	+	L	-	+
3	0	0	-	L	-
4	+	NA	+	+	+
5	NA	NA	-	-	-
6	NA	NA	-	NA	L
7	NA	NA	NA	+	L
MFHT(cm)					
20	-	-	NA	NA	-
30	+	+	0	NA	+
40	L	NA	0	+	0
50	L	NA	0	L	0
60	NA	NA	-	0	-
70	NA	NA	NA	-	L
MGHT(cm)					
20	-	-	NA	NA	-
30	-	+	0	+	+
40	0	NA	L	NA	0
50	+	NA	0	-	-
60	NA	NA	+	NA	0
70	NA	NA	+	-	0
80	NA	NA	NA	+	0
MSDMHT(cm)					
10	NA	NA	-	NA	-
20	NA	-	L	+	0
30	-	NA	0	L	0
40	L	-	-	-	-
50	-	+	+	NA	+
60	NA	NA	+	-	0
70	+	NA	-	+	0
80	-	NA	NA	NA	L

Measurement class	Dec-Feb	Mar-May[a]	Jun-Aug	Sep-Nov	Total
(continued)					
MDMHT(cm)					
0	-	-	+	0	-
10	+	+	-	0	+
FCC(%)					
1-5	+	NA	-	NA	-
6-25	-	+	-	-	-
26-50	0	-	+	+	+
51-75	NA	+	L	NA	L
GCC(%)					
1-5	-	NA	+	+	-
6-25	+	-	L	-	L
26-50	L	+	0	-	+
51-75	NA	NA	-	+	0
MSDMCC(%)					
0	NA	NA	-	+	+
1-5	-	-	L	L	L
6-25	L	-	-	-	-
26-50	0	+	+	NA	+
51-75	+	NA	NA	NA	0
MDDMCC(%)					
0	NA	NA	+	0	+
1-5	0	NA	L	L	L
6-25	-	-	0	L	-
26-50	+	+	-	NA	+
GRNDCC(%)					
1-5	NA	NA	-	NA	-
6-25	+	+	0	0	+
26-50	-	-	-	0	-
51-75	-	-	+	-	0
76-95	NA	NA	+	+	L
COB(%)					
0-30	NA	-	+	NA	+
40	-	NA	-	NA	-
50	0	+	-	NA	+
60	-	NA	-	0	-

Measurement class	Dec-Feb	Mar-May[a]	Jun-Aug	Sep-Nov	Total
(continued)					
70	NA	NA	-	L	-
80	0	NA	NA	0	-
90	+	NA	NA	0	0

[a]Data collected during this quarter were only collected in 1985 except for OV, which was collected in 1984 also.

lowest and highest categories available were used more than expected, while those in the middle ranges were used less than expected. Over the entire year, maximum grass heights in the 20 and 50-cm ranges were used less than expected, while those in the 30-40, and 60-80-cm ranges were used more, or in proportion to their availability.

Use of habitats with respect to maximum standing dead height in the lowest and highest available categories for each quarter was generally less ($\underline{P} < 0.05$) than expected except for the September-November period when these categories were used more than expected and in March-May when the highest available category was used more than expected (Table 12). For the entire December-November period, habitats with mean maximum standing dead material in the 10 and 40-cm ranges were used less than expected, while those in the 20-30 and 50-80-cm ranges were used either more or in proportion to their availabilities.

Habitats with mean maximum down dead matter depths in the zero category (i.e., 0-4.9 cm) were used less than expected during the December-May periods and for the entire year, more than expected during June-August, and in proportion to its availability during September-November (Table 12). Habitats with mean down dead material maximum heights in the 10-cm range (i.e., 5-14.9 cm) were use more than expected during December-May and for the entire year average, and less than expected in June-August.

Relative to forb canopy coverage, male and nonreproductive females used habitats with mean forb canopy cover in the higher available coverage classes more ($\underline{P} < 0.05$) than expected or in proportion to their availability for all quarters and for the entire year data (Table 12).

Except for the December-May period, habitats with the lowest available mean forb canopy coverage were used less than expected.

During December-May, habitats with mean grass canopy coverage in the highest available ranges (i.e., 6-50% for December-February and 26-50% for March-May) were used more ($\underline{P} < 0.05$) than expected while habitats with the lowest available means were used less than expected (Table 12). In the summer months of June-August, habitats with mean grass cover of 1-25% were used more than expected, while areas with the highest (51-75%) mean grass cover available were used less than expected. During the fall months, habitats with low (1-5%) and high (51-75%) grass cover were used more than expected, while habitats with mean grass cover in the 6-50% range were used less than expected. Over the entire year, males and nonreproductive females were found more ($\underline{P} < 0.05$) often in habitats with mean grass cover in the 26-50% range. Habitats with mean grass cover in the 1-5% range were used less often for the entire year than would be expected given the availability of habitat with those characteristics.

In general, except for the September-November period, habitats with the highest available mean standing dead material coverage were used more ($\underline{P} < 0.05$) than expected, while those habitats with means in the lowest available categories were used less than expected (Table 12). During September-November, this situation was reversed and habitats with the lowest available standing dead material coverage were used more while those with the highest available mean (6-25%) were used less than expected. For the entire December-November period, habitats with mean standing dead canopy coverages of <6 and 26-50% were used more than expected, while those in the 6-25% range were used less than expected. Habitats with standing dead cover in the 51-75% range were used in proportion to their availability.

With respect to down dead matter coverage, habitats with means in the 26-50% range were used more than expected during the December-May period, and less than expected during the summer months (Table 12). During the summer months, more habitats than expected with <6% down dead matter cover were used. On the average over the entire year, more habitats were used than expected with down dead matter cover in the <6% and the 26-50% ranges, while habitats in the 6-25% range were used less than expected.

During the December-May period, habitats with the lowest mean bare ground coverage available (6-25%) were used more than expected, while those with mean bare ground cover in the 26-75% range were used less than expected. During the summer, habitats with mean ground cover of 1-5 and 26-50% were used less than expected while those with means in the 51-95% range were used more than expected given their availability. During the fall, habitats with mean bare ground cover of 51-75% were used less than expected, those in the 76-95% range more than expected, and those with means in the 6-50% range in proportion to their availability. For the entire December-November period, habitats with mean bare ground coverage of 1-5 and 26-50% were used less than expected, while those with means in the 6-25% range were used more than expected. Habitats with means in the 51-95% range were used in proportion to their availability over the entire year.

During December-February winter period, habitats with mean overhead canopy obstruction in the lowest available category were used less than expected, while habitats with means in the 90% range received more use than expected. During summer, this situation was reversed, with habitats in the mean 0-30% range being used more than expected while those in the 40-70% range were used less than expected. For the entire December-November period, habitats with mean overhead canopy obstruction values in the 0-30 and 50% range were used more than expected, while those in the 40 and 60-80% ranges were used less than expected. Habitats with mean overhead obstruction values of 90% were used in proportion to their availability.

Nests

Twenty-six nests were found during the study, 5 of which were found accidentally by various personnel in the course of other activities (Table 13). Clutch size for nests of unknown status (initial or renesting attempts) averaged 13 eggs (_N_ = 16). For known renesters, clutch size averaged 8.2 eggs, ranging from 7-12 eggs (_N_ = 4). Nest success was 60, 44, and 17%, respectively, for the 3 years of the study, and averaged 35%. Nest success as calculated using Mayfield's method (Johnson 1979) differed from these estimates by only a few percent, indicating that most nests were found soon after incubation had begun. Skunks were held responsible for 41% of the nest losses, coyotes (_Canis latrans_) or opossums (_Didelphis virginianus_) for another 24%, while unknown agents accounted for 35% of the nest losses. In addition to the low nesting success observed during 1985, 2 hens were killed on the nest, at least 1 of which was probably due to mammalian predation.

Table 13. Number and success of Attwater's prairie chicken nests found on APCNWR during 1983-85.

Year	N	% Success
1983	5	60
1984	9	44
1985	12	17
1983-85	26	35

During the 3-year period, 50, 57, and 12.5% of the radioed hens which were observed for a long enough period to have attempted a nest, were successful in leaving the nest with young, for an average of 38% from 1983-85. Hatchability of eggs in successful nests averaged 85%. However, 1 of the accidentally found nests contained 7 unhatched eggs out of a total clutch of 15. It is possible that this nest represented a dump nest. No losses of entire nests were attributed to fire ants (Solenopsis spp.), although the death of an unhatched chick in a pipped egg, and of a hatched chick found dead in the nest could possibly have been due to fire ant predation. The earliest hatch dates for radioed birds were during the 2nd week of May, although a non-radioed brood was observed during the last week of April in 1983. The latest radioed hen which successfully hatched young left the nest during the 3rd week in June, 1985.

In terms of habitat selected by hens for nesting, 65% of all nests were found in 4th-year or older burns, and 85% were found in 3rd-year or older burns (Table 14). Eighty-five percent of the nests were found on loamy range sites. Nest success also tended to be somewhat higher on 3rd-year and older burns at 36% as compared to the 26% nest success observed for heavily grazed pasture and the 2nd-year burns. OV readings at nest sites averaged 2.3 dm.

Broods

A total of 8 radioed hens was successful in leaving the nest with chicks. These broods experienced an estimated 48% mortality (i.e., an average 48% of all broods were lost) during the 1st 4 weeks after

Table 14. Distribution and success of nests within habitat types on APCNWR during 1983-85. Unless otherwise indicated habitats are burned (B followed by age of the burn) or unburned (U) followed by the range site grouping (L=loamy, S=sandy).

Habitat	*N*	% Success
Heavily Grazed Pasture[a]	1	0
B2L	2	50
B2S	1	0
B3L	4	50
B3S	1	100
B4L	7	0
B4S	1	100
UL	9	44

[a]Nest located in a pasture adjacent to APCNWR.

leaving the nest, and 44% during the 2nd 4 weeks, although no statistical difference ($P > 0.05$) was observed between these 2 periods (Table 15). Overall, mortality of entire broods for an 8-week brooding period was estimated at 66%. No attempt was made to determine losses of individuals within brood units. It was assumed that 2 of the 3 broods observed during 1983 were lost when the hens made movements of approximately 1.8 and 3.1 km during the 2nd week in June, as young were not observed with these hens when flushed at approximately 6 weeks after leaving the nest. The remaining hen which retained her brood during 1983 also made a fairly extensive movement of 1.6 km during approximately this same time interval. These hens, in general, moved from cover of moderate density to lighter, more open cover found in coarse sand areas (2 hens) and fallow rice fields (1 hen). During 1984, causes of observed brood mortality included 2 which were assumed lost during heavy rain storms occurring approximately 2 weeks after these broods left the nest, and 1 which was lost when the hen was predated. The only radioed hen successful in leaving the nest with a brood in 1985 retained that brood through the end of the study, at which time the brood was over 6 weeks old. Another source of brood mortality was observed when at least 2 unmarked broods were disturbed and scattered by refuge personnel on at least 4 occasions while disking a weedy patch in preparation for planting crops during 8-10 May 1985. At least 1 chick was killed directly.

The maximum movement observed for a brood between successive locations was approximately 705 m in 4 hours, or 176 m/hour, by a 1-2-day-old brood. Another approximately 10-day-old brood moved 1.0 km in a

Table 15. Estimated survival of broods ($\underline{N}$ = 8) monitored by radio telemetry during 1983-85. No attempt was made to determine survival of individuals within a brood.

Age(weeks)	DSR[a]	Survival(%)	95% CI Lower	95% CI Upper
0-4	0.9770	52.1	27.0	99.2
4-8	0.9794	54.8	23.7	100.0
0-8	0.9808	33.9	12.7	88.2

[a]Estimated daily survival rate

12-hour period, or 83 m/hour. This brood was later assumed lost when the hen made the 3.1-km movement previously discussed. By 7-10 days post-hatching, hens with broods had moved an average 0.7 km from their nest sites.

Based on the relatively extensive movements during roughly the same time interval in early June 1983, brood data were separated into 2 time periods for analysis. Time period 1 corresponded to the brooding period prior to 15 June, while period 2 corresponded to brooding activities observed after 15 June.

Chi-square tests of independence and Bonferroni confidence intervals indicated that 2nd-year burned areas were used more ($\underline{P} < 0.05$) than expected, while 3rd-year and older coarse sand areas and all crops and fallow areas were used less than expected during the brooding period prior to 15 June (Table 16). In fact, none of the 8 radioed broods were ever observed in refuge crops or fallow areas during the study. After 15 June, 3rd-year and older coarse sand areas were used more than would be expected given their availability, while 2nd-year burns, and 3rd-year plus loamy and sandy burns, as well as crop and fallow areas were used less than expected.

A Chi-square test of independence indicated that habitat use by broods prior to 15 June was different ($\underline{P} < 0.001$) than that after 15 June. Higher than expected use of 2nd-year loamy burns during the 1st period, and higher than expected use of 3rd-year plus coarse sand burns during the 2nd period contributed most to the total Chi-square value. Analysis of overall brood habitat indicated greater use of 2nd-year burns, and 3rd-year and older coarse sand burns than would be

Table 16. Habitat use by broods (N = 8) during 1983-85. A + in the selection column indicates use was greater ($P < 0.05$) than expected given the availability of the habitats within the composite annual home range of brood hens, - = less than expected use, 0 = no difference, L = habitat was lumped with the habitat above for the Chi-square analyses. Habitats are as indicated in Table 2.

	<15 Jun (N[a] = 58)		>15 Jun (N = 60)		Total (N = 118)	
Habitat	Use(%)	Selection	Use(%)	Selection	Use(%)	Selection
B1L	10.3	0	18.3	0	14.4	0
B1S	0.0	L	0.0	L	0.0	L
B2L	51.7	+	0.0	-	25.4	+
B2S	1.7	L	0.0	L	0.8	L
B2CS	0.0	L	3.3	L	1.7	L
B3+L	29.3	0	11.7	-	20.3	-
B3+S	5.2	0	1.7	-	3.4	-
B3+CS	0.0	-	61.7	+	31.4	+
Refuge Crop	0.0	-	0.0	-	0.0	-
Fallow Cult.	0.0	L	0.0	L	0.0	L
Fallow Rice	0.0	L	0.0	L	0.0	L

[a]Number of daily locations.

expected, and less use of 3rd-year and older loamy and sandy burns, and of all crop and fallow areas. First-year burns were used approximately in proportion to their availability.

Correlation of brood habitat use in relation to its availabilty within the composite annual home ranges of brooding hens, with the vegetative structural characteristics and their coefficients of variation, and with seed and insect availabilities on the vegetation transects, revealed no significant ($\underline{P} > 0.05$) relationships in the way these variables varied with respect to each other. Comparisons of the availability of habitats on the refuge having specific mean structural characteristics, with the use of these habitats are presented in Table 17. In general, prior to 15 June, broods used habitats with OV values in the 2-dm range more ($\underline{P} < 0.05$) than expected given the availability of such habitat on the refuge, while habitats in the 0.5-1.5-dm range were used less than expected. Habitats with mean OV values of 2.5 dm were not used in significantly different proportions than their availabilities would suggest during this part of the brooding period. During the period after 15 June, broods used habitats in the 0.5-1-dm range more than expected, while those with mean OV's in the 1.5-2.5-dm range were used less than expected. Over the entire brooding period, broods used habitats in the 0.5-1-dm OV range more than expected, those in the 1.5-dm range less than expected, and those in the 2-2.5-dm range in approximate proportion to their availability.

Mean maximum forb heights used by broods indicated that habitats in the 50-cm range were used more than expected while those in the 40-cm range were used less than expected prior to 15 June (Table 17). After

Table 17. Comparison of use and availability of mean structural characteristics of habitats used by broods during 1983-85. A + indicates greater ($P < 0.05$) use than expected, a - = less use than expected, 0 = no difference between use and availability, L = class was lumped with those above for the Chi-square analysis. Vegetation measurements are as indicated in Table 7.

Measurement	<15 Jun	>15 Jun	Total
OV(0.5 dm)			
1-2	-	+	+
3	-	-	-
4	+	-	0
5	0	-	0
MFHT(cm)			
30	0	0	0
40	-	+	-
50	+	-	0
MGHT(cm)			
40	0	0	0
50	0	0	0
60	0	-	0
MSDMHT(cm)			
10	0	0	0
20	-	+	0
30	+	-	+
40	-	-	-
50	0	-	0
MDDMHT(cm)			
0	0	+	+
10	0	-	-
FCC(%)			
6-25	-	0	-
26-75	+	0	+
GCC(%)			
6-25	-	+	0
26-50	+	-	0
SDMCC(%)			
0-5	0	0	0
6-25	0	0	0
26-50	0	-	0

Measurement	<15 Jun	>15 Jun	Total
(continued)			
DDMCC(%)			
0-5	0	+	+
6-25	0	+	+
26-50	0	-	-
GRNDCC(%)			
6-25	0	-	-
26-50	+	-	+
51-75	-	+	0
COB(%)			
20	-	0	0
30	0	L	L
40	-	+	0
50	-	-	-
60	+	-	+
70	0	-	0

15 June these preferences were exactly reversed. Mean maximum grass heights for the most part were used in proportion to their availability except after 15 June when habitats with mean maximum grass heights in the highest available range (60 cm) were used less than expected.

No definite generalizations were detected for brood use prior to 15 June with respect to standing dead matter height (Table 17). However, after 15 June, broods used areas with mean maximum heights greater than 20 cm less than expected if their use of habitat had been random with respect to its availability. Areas were used in approximate proportion to their availabilities prior to 15 June with respect to mean maximum down dead matter height. However, after that time, broods used habitats in the 0-cm range (i.e., 0-4.9 cm) more than expected while those in the 10-cm range (5-14.9 cm) were used less than expected.

Habitats with mean forb canopy coverages in the 6-25% range were used less than expected by broods prior to 15 June, while areas with means in the 26-75% range were used more than expected during this period (Table 17). After 15 June, habitats were used in approximate proportion to their availabilities with respect to mean forb canopy coverage. However, overall broods appeared to favor areas with mean forb canopy coverages in the 26-75% range, while using areas in the 6-25% range less than expected. With respect to mean grass canopy coverage, early in the brooding period, broods used areas with mean grass coverages in the 25-50% range more than expected, while those in the 6-25% range appeared to have been avoided. After 15 June, this situation was reversed, and mean grass coverages in the 6-25% range were used more while those in the 25-50% range were used less than expected.

Throughout the brooding period, broods used habitats in approximate proportion to their availability with respect to standing dead matter coverage, except for the latter part of the brooding period when areas with standing dead matter cover in the 26-50% range were used less than expected (Table 17). Regarding down dead material cover, broods used areas in approximate proportion to their availability prior to 15 June, while after 15 June habitats with mean down dead matter coverage in the 6-25% range were used more than expected, and those in the 26-50% range were used less than expected.

Areas used during the early brooding period with mean bare ground coverage of 26-50% were used more than expected if all habitats were used in proportion to their availability, while those with means in the 51-75% range were used less than expected (Table 17). After 15 June, areas with mean 6-50% bare ground coverages were used less than expected while those in the 51-75% range were used more than expected. Overall, broods used areas with mean bare ground coverage of 26-50% more, and areas with 6-25% less, than expected. Habitats with mean bare ground coverage of 51-75% were used in approximate proportion to their availability.

With respect to overhead canopy obstruction, broods prior to 15 June used areas in the 60% range more, while those in the 20, 40, and 50% ranges were used less, than expected. After 15 June, broods appeared to prefer habitats that were more open above, using those areas with 20-30% overhead obstruction in approximate proportion to their availability, while areas with means in the 40% range were used more than expected. Habitats with means in the 50-75% range appeared to have been avoided during the latter period.

Predator Abundance and Activity

A total of 1,823 km of spotlight predator census route was driven during the study (Table 18). In general, fewer kilometers were driven per predator observed in 1983 than in 1984-85. However, skunks appeared to be generally more abundant in 1983 and 1985 than in 1984. Looking at the June-August data, the only quarter in which data was collected during all 3 years to negate the effects of seasonal changes in sightability, skunks were generally more abundant in 1983, less abundant in 1984, and intermediate in abundance during 1985.

Relative to predator associations with habitat types found along the census routes, only burns older than 4 years on loamy and sandy areas had total predator associations, adjusted for availability, with 95% confidence intervals which were greater than 1 (Table 19). All 95% confidence intervals on these habitat assocations for skunks contained 1. An association adjusted for habitat availability equal to 1 would indicate an association equal in proportion to the availability of the habitat along the census route.

Cattle Use and Impacts on Habitats

Pairwise comparisons of observed effective stocking densities (AU/ha) for 1984 and 1985 are presented in Tables 20 and 21, respectively. In general, during 1984, effective stocking densities were statistically higher ($\underline{P} < 0.05$) on 1st-year burn loamy areas than for all other habitats except 4th-year burn sandy areas and fallow rice

Table 18. Kilometers driven/potential predator observed along a spotlight census route during 1983-85.

Period	Km censused	Skunks	Opossums	Armadillos	Coyotes	Bobcats	Raccoons	Total
1983								
Jun-Aug	135	19.3	-	33.8	-	-	-	12.3
Sep-Nov	186	37.2	93.0	-	-	186.0	-	23.2
Total	321	26.8	160.5	80.2	-	321.0	-	16.9
1984								
Dec-Feb	280	70.0	280.0	-	-	-	-	56.0
Mar-May	171	57.0	85.5	57.0	171.0	-	-	19.0
Jun-Aug	253	63.2	253.0	63.2	-	-	-	28.1
Sep-Nov	227	25.2	75.7	113.5	-	-	133.5	14.2
Total	931	46.6	133.0	103.4	931.0	-	465.5	23.9
1985								
Dec-Feb	121	60.5	-	121.0	-	-	-	40.3
Mar-May	238	23.8	79.3	-	-	-	-	18.3
Jun-Aug	212	30.3	-	-	-	-	-	30.3
Total	571	30.1	190.3	571.0	-	-	-	24.8
1983-85	1,823	35.7	151.9	130.2	1,823.0	1,823.0	911.5	22.5

Table 19. Percent of total predators and skunk locations, adjusted to common habitat availability, associated with habitat types along a census route during 1983-85. Unless otherwise indicated, habitats are burned (B followed by age of the burn) and unburned (U) followed by the range site grouping (LS=loamy or sandy groups lumped, CS=coarse sand).

Habitat	Total Predators			Skunks		
	% Assoc.	Lower	Upper	% Assoc.	Lower	Upper
B1LS	1.6	0.6	2.4	1.3	0.3	2.3
B1CS	4.6	0.0	9.7	4.9	0.0	11.5
B2LS	1.5	0.9	2.1	1.5	0.7	2.3
B2CS	2.5	0.0	4.2	2.6	0.0	6.1
B3LS	1.5	0.6	2.4	0.8	0.0	1.7
B3CS	2.8	0.0	6.6	4.3	0.0	10.2
B4LS	2.0	0.9	3.1	1.9	0.5	3.3
B4CS	0.8	0.0	2.4	1.3	0.0	3.8
B5LS	4.6	1.1	8.1	3.7	0.0	7.8
ULS	1.4	1.1	1.7	1.2	0.8	1.6
UCS	1.1	0.5	1.7	1.3	0.5	2.1
Fallow Rice	0.9	0.0	1.9	1.0	0.0	2.3
Refuge Crop	1.8	0.0	3.8	2.0	0.0	4.6
Fallow Cult.	2.1	0.0	4.4	2.2	0.0	5.1
Adj. Pasture[a]	1.5	0.0	3.5	2.3	0.0	5.4

[a]Habitat located adjacent to the refuge.

Table 20. Comparison of effective cattle stocking densities (AU/ha) on APCNWR habitat types as determined from standardized cattle counts for 1984. A + indicates a higher ($P < 0.05$) mean effective stocking density for column habitats as compared to row habitats, a - indicates a lower mean stocking density, 0 indicates no difference. Habitats are as indicated in Table 2.

Habitat	B1L	B1S	B2L	B3L	B3S	B4S	B5L	B5S	B5CS	UL	US	UCS	Fallow Rice
B1L	.	-	-	-	-	0	-	-	-	-	-	-	0
B1S	+	.	0	0	0	0	0	0	0	0	0	0	+
B2L	+	0	.	0	0	0	-	0	0	0	0	+	+
B3L	+	0	0	.	0	0	-	0	0	0	0	0	+
B3S	+	0	0	0	.	+	0	+	0	0	+	+	+
B4S	0	0	0	0	-	.	-	0	0	0	0	0	0
B5L	+	0	+	+	0	+	.	+	0	0	+	+	+
B5S	+	0	0	0	-	0	-	.	0	0	0	0	+
B5CS	+	0	0	0	0	0	0	0	.	0	0	0	+
UL	+	0	0	0	0	0	0	0	0	.	0	+	+
US	+	0	0	0	-	0	-	0	0	0	.	0	+
UCS	+	0	-	0	-	0	-	0	0	-	0	.	+
Fallow Rice	0	-	-	-	-	0	-	-	-	-	-	-	.

Table 21. Comparison of effective cattle stocking densities (AU/ha) on APCNWR habitat types as determined from standardized cattle counts during 1985. A + indicates a higher ($\underline{P} < 0.05$) mean effective stocking density for column habitats as compared to row habitats, a - indicates a lower mean stocking density, 0 indicates no difference. Habitats are as indicated in Table 2.

Habitat	B2L	B2S	B3L	B4L	B4S	B5S	UL	US	UCS	Fallow Rice
B2L	.	0	-	0	0	0	-	0	0	+
B2S	0	.	0	0	0	0	0	0	0	+
B3L	+	0	.	+	0	0	0	0	+	+
B4L	0	0	-	.	0	0	0	0	0	+
B4S	0	0	0	0	.	0	0	0	+	+
B5S	0	0	0	0	0	.	0	0	0	0
UL	+	0	0	0	0	0	.	0	+	+
US	0	0	0	0	0	0	0	.	0	+
UCS	0	0	-	0	-	0	-	0	.	+
Fallow Rice	-	-	-	-	-	0	-	-	-	.

fields, which were not significantly different (Table 20). Observed effective stocking densities averaged 0.27 AU/ha on the 1st-year burn loamy areas and 0.23 AU/ha on fallow rice fields during 1984, while stocking rates on the refuge as a whole averaged 0.19 AU/ha/year (APCNWR, unpubl. data). Mean effective stocking densities observed on unburned coarse sand areas were higher than that for 2nd, 5th, and unburned loamy areas, and 3rd-year burn sandy areas. Effective stocking densities observed on unburned coarse sand areas averaged 0.13 AU/ha which was lower than the average stocking rate for the refuge as a whole. Effective stocking densities for 5th-year loamy burns were generally lower than all other habitats on the cattle census route except 1st and 3rd-year sandy burns, and unburned loamy coarse sand burns which were not statistically different during 1984.

During 1985, mean effective stocking densities on fallow rice fields were greater ($\underline{P} < 0.05$) than for all other habitats on the cattle census route except 5th-year sandy burns which were not different (Table 21). Effective stocking densities on refuge fallow rice fields averaged 0.34 AU/ha, while the stocking density for the whole refuge was 0.17 AU/ha (APCNWR, unpubl. data). Mean stocking densities for unburned coarse sand areas were greater than those for 3rd-year and unburned loamy areas, and for 4th-year sandy burns. Second-year loamy burns had mean effective stocking densities which were higher than those observed on 3rd-year and unburned loamy areas.

With respect to the effects of time on the difference in vegetation characteristics inside and outside the grazing exclosure plots, differences over time were observed for OV ($\underline{P} < 0.002$) and maximum forb height ($P < 0.001$). Differences in OV were less ($P < 0.05$) when taken during the 2nd quarter after establishment of the grazing plots than in either quarters 3 or 4. Differences in maximum forb height steadily increased with time since grazing exclusion, with differences during quarter 3 greater than in quarter 2, and those during quarter 4 greater than those for quarter 3.

Habitats differed ($P < 0.05$) in their response to grazing exclusion, with significant differences observed for OV, maximum grass height, maximum forb height, and standing dead matter coverage (Table 22). References to habitats which follow are with respect to their status at the beginning of grazing exclusion. Unburned sand areas showed the greatest response in OV, although not statistically greater than sandy areas which were 1st and 3rd-year burns when the exclosure plots were established. Unburned loamy areas showed the least OV response, but were not statistically different from unburned coarse sand areas or loamy areas which were 3rd-year burns at the start of grazing exclusion. First-year burn sandy areas responded most with respect to maximum grass height, with all other habitats being similar in the response of maximum grass height. First-year sandy areas again showed the greatest maximum forb height response, although being statistically similar to 1st-year loamy burns and unburned sandy and coarse sand areas. Standing dead material coverage showed the greatest response on unburned sandy, unburned coarse sand, 3rd-year loamy burns, and 1st-year sandy burns.

Table 22. A comparison of habitat responses to 1.1 m^2 grazing exclosures established in June 1984, blocking against the effects of time. Habitats are either burned (B followed by year of burn) or unburned (U), followed by the range site grouping (L=loamy, S=sandy, CS=coarse sand). Vegetation measurements are as indicated in Table 7.

Habitat	Measurement[a]			
	OV	MGHT	MFHT	SDMCC
UL	E	B	C	C
US	A	B	AB	A
UCS	CDE	B	ABC	A
B82L	DE	B	BC	C
B82S	ABC	B	BC	A
B83L	BCD	B	BC	AB
B83S	BCD	B	BC	BC
B84L	BCD	B	AB	C
B84S	AB	A	A	A

[a]Habitats with a common letter within a measurement type are not different ($P > 0.05$) in their degree of response to grazing exclosure. Habitats with the letter A showed the greatest response, B the next greatest, etc.

DISCUSSION

The density of Attwater's prairie chickens on the refuge, at an estimated 8.9 males/259 ha (1 mi^2) excluding the marshland habitat, is low compared to many other regions, even though populations on the refuge were at record levels during 1985. Densities on unmanaged habitats reported in the literature ranged for 0.6 males/259 ha in Ontario (1950) to 38.8 males/259 ha (1950) in Kansas (Hamerstrom et al. 1957:90-111). Lehmann (1941:7) estimated that in areas of favorable habitat, total populations of Attwater's historically approached 640/259 ha (1/acre), although this estimate is perhaps overly generous. Population densities reported on areas of managed greater prairie chicken habitat ranged from 32-43 males/259 ha for continuous habitat in Kansas, to 80-107 males/259 ha of ecologically patterned nesting habitat in Illinois (Missouri Dep. Conserv. 1984). Additionally, Arthaud (1968) observed a density of 68 males/259 ha on 700 ha of managed prairie in Missouri.

Admittedly, approximately 24% of the refuge is composed of coarse sandy soils along the San Bernard River which are of questionable quality to prairie chickens during the critical winter and nesting periods. Excluding this coarse sand habitat, densities of 12.1 males/259 ha were observed during 1985, which is still low compared to reported densities for other managed areas. Although the coarse sand areas will probably never be good nesting and wintering habitat, steps can be taken to increase its quality from present levels. Observations on cattle grazing in this study indicated that cattle grazed coarse sand areas at a higher intensity than 2nd-year and unburned loamy areas, which were also major habitats on the refuge comprising an average 7.4 and 10.4% of the total area, respectively. Although observations on cattle grazing exclosure plots indicated that total vegetation biomass (as indicated by OV measurements) on coarse sand areas did not respond well to exclusion of cattle grazing, it should be pointed out that the exclosures were established during a drought period. Coarse sand soils are particularly sensitive to drought conditions. Therefore, a greater response to grazing exclusion probably could be expected on these soils during periods of more normal precipitation. Although cattle grazing should not be completely eliminated on these areas, grazing should be more closely monitored and cattle moved when grassland species begin to show signs of stress.

Mortality

Although adult mortality estimates were unusually high if all birds for which signals were lost were considered mortalities, evidence has already been discussed which suggests that this is not a valid assumption. True population mortality rates, as suggested previously, probably lie somewhere between the 64.5% estimate considering only birds found dead, and the 89.2% estimate considering all lost birds as mortalities. The mid-point of this range is 77%, which is the estimated turnover rate that Lutz (1979) observed for banded male Attwater's in Refugio County, Texas. However, Horkel (1979) also working with banded male Attwater's in Refugio County, observed a lower mortality rate of 57%. Hamerstrom and Hamerstrom (1973) observed a 52% annual mortality for banded Wisconsin greater prairie chickens in unhunted populations.

Although mortality estimates in this study appear to be somewhat high, they are within reasonable ranges given the uncertainty associated with them. Intensive banding studies should be undertaken on the refuge to more accurately assess the turnover rate in that population.

Nesting success during 1983 (60%) and 1984 (44%) was higher than the 31-42% previously reported for Attwater's nesting success (Lehmann 1941, Horkel 1979, Lutz 1979, Lawrence 1982). However, a dramatic decrease in nest success was observed in 1985. In addition to the poor nest success during that year, 2 hens were killed on the nest. Mortalities associated with nests were not observed in the previous 2 years. The 35% average nest success for the 3 years of the study was within the range previously reported for Attwater's, but slightly lower than the average 42% reported in all studies of both Attwater's and greater prairie chicken nesting success.

Several possible reasons may account for the nesting problems observed during 1985. First, the sample of nests may not have been representative of the population due to the small sample sizes observed. However, a comparison of young/adult ratios obtained by helicopter counts during July indicate the same trends observed in the nesting data. During 1983 and 1984, young/adult ratios of 3.9:1 and 2.1:1 were observed, respectively, while in 1985, only 1.1 young per adult were observed (APCNWR, unpubl. data). Another possible explanation may be that predator populations were substantially higher during 1985. However, the predator census data do not support that contention. In fact, more predators were observed per kilometer driven during 1983 when nest success was the highest observed during the study, than were observed during 1984 or 1985.

A more likely explanation for the decreased nest success during 1985 can probably be found in the response of available cover on the refuge to the below normal rainfall during April-September in 1984, a period corresponding to a majority of the growing season for warm season grasses in that area. As a result, cover going into the 1985 nesting season was down considerably as compared to 1983 and 1984. Two possible impacts of this decreased cover include (1) concentration of nests into remaining acceptable cover, and (2) changes in small mammal species composition which serve as the principal prey base for nest predators (Krapu et al. 1970). Dunn (1977) found that predation of tits (*Parus* spp.) was proportional to their density. Darrow (1945) observed that decreased abundance of buffer prey resulted in increased fox activity, which in turn increased the probability that ruffed grouse (*Bonasa umbellus*) would be predated. Byers (1974) observed a significant correlation between blue-winged teal (*Anas discors*) nesting success and the number of small mammals caught on trap lines, suggesting that small mammal populations buffered nesting success.

Several investigators have reported on estimates of individual survival within broods by comparing counts of brood size at various intervals during the brooding season with the mean number of chicks observed in early broods, or to the number estimated to have left the nest (i.e., the mean clutch size). Such estimates have indicated individual mortality within broods during the 1st 4-6 weeks of 46-50% (Lehmann 1941, Yeatter 1943), and by 10 weeks averages 56% (Bowman and Robel 1977). However, few have reported on the mortality of the brood unit as a whole. Horkel (1979) observed that of 3 broods of known fate, 2 were completely lost within 31 days after leaving the nest. Svedarsky (1979) presented data on 9 broods of radioed greater prairie chicken hens in Minnesota which resulted in an estimated 66% mortality of brood units during the 1st 4 weeks posthatching, which was higher than the 48% observed in this study. In fact, the estimated whole brood mortality of 66% by 8 weeks observed on APCNWR equaled the mortality Svedarsky observed in the 1st 4 weeks. Lehmann (1941) indicated that young 6-8 weeks old were capable of independent survival. Therefore, it is unlikely that any entire broods were lost after 6 weeks of age. If that assumption is true, then mortality of brood units in our study averaged 60% over the brooding period (daily survival rate = 0.9786).

Average population parameters such as those discussed here are important in identifying major problems in the population. For example, based on the data discussed so far, it appears that survival of broods was low for the population of prairie chickens on APCNWR. Accordingly, management attention should be addressed toward reducing this mortality. Recommendations for accomplishing this objective will be discussed later. However, data averages do not provide the continuing long-term information necessary for managers to "fine-tune" the system as problems develop. Data on adult mortality, nesting success, and recruitment of young into the population should be collected on a yearly basis to allow managers to assess changes in management strategies, and to identify targets for improvement.

Movements and Home Ranges

The mean home range size of 360 ha for males in this study was almost twice as great as the median 184 ha reported by Jurries (1979) for male Attwater's in the ricebelt region of Texas, and half as great as Jurries reported for males in native prairie areas. For females, a mean 595 ha annual home range was observed, again slightly more than twice as great as the 294 ha median Jurries observed for ricebelt females, but similar to the 603 ha for native prairie females in Jurries' study. Other intensive studies on prairie chicken home range size (e.g., Robel et al. 1970a, Horkel 1979) presented only monthly home range sizes, making direct comparisons with this study impossible.

Although the magnitude of movements differed, seasonal movement patterns observed in this study were similar to those observed by Robel et al. (1970a) with greater prairie chickens in Kansas, and Horkel (1979), working with the Attwater's. However, females in this study moved comparatively more during the nesting season than in especially Horkel's study. Birds on Horkel's study area moved less on the average than birds in this study except during October and November for males, and October-March for females, when Horkel observed slightly greater movements. Movements observed by Robel et al. (1970a) were consistently greater than those observed in this study except during January, September, and December for males.

Although no monthly data on movements were presented by Jurries (1979), he indicated that once the booming season and the associated attachment with the booming ground had ended, prairie chickens began summer movements. Although movements between successive days were not great, Jurries observed that cumulative distances moved by males often approached 5-6.5 km in the native prairie region. However, Jurries (1979) indicated that males in the ricebelt region never moved more than 3.2 km from the booming ground. Movements by females followed patterns similar to males, although distances moved were generally less. Extreme movements observed by Jurries for females were approximately 3.2-4.8 km in native prairie and 2 km in the ricebelt region.

Average movements by female in this study were similar to those observed by Jurries in the native prairie region, although maximum movements of 5.3 and 5.8 km by 2 females in 1985 were observed. Five of seven extensive female movements during this study were to fallow rice fields to the south of the refuge, and often occurred after the hen had lost a nest or brood. Once making these moves, the hens generally remained in the same area until returning in the late fall. One hen monitored during all 3 years of the study made moves of this nature all 3 years, returning to nest in the same area each year. In fact, this hen's 1st and 2nd year's nests were within 15 m of each other.

Only 2 males were observed making what were considered extensive movements. These averaged only 3 km. It is possible that males making more extensive movements were lost. Periodic attempts to locate lost birds in areas surrounding the refuge suggest that this was not the case. However, it is known that at least 2 hens moved away from the refuge and were lost for a period before moving back again.

Brood Movements

Movements observed in this study, although substantial in some cases, were not excessive when compared to those reported in other studies. Cebula (1966), Viers (1967), and Silvy (1968) in Kansas all observed movements of 3.2 km, and Svedarsky (1979) in Minnesota of 3.8 km, within 1 week after hatching. Silvy (1968) observed movements of 172 m/hour for a radioed hen with a brood during periods of movement. Broods observed by Svedarsky (1979) had moved an average 983 m by 2 weeks after leaving the nest. Broods on APCNWR moved an average 700 m from the nest during the 1st week to 10 days, and then remained in that area for some time, moving less than 300 m/day on the average. Lehmann (1941) also observed brood movements of $<$300 m/day, although he indicated that the 1st few weeks after hatching were spent in close proximity to the nest. As in this study, particularly in 1983, Lehmann (1941) observed extensive movements involving both young and adults beginning around the 1st of June. Lehmann indicated that movements in his study were generally toward the vicinity of surface water where shade was present. Jurries (1979) observed differences in the distances Attwater's broods moved after hatching between the ricebelt and native prairie regions of Texas, and attributed these differences to a difference in the distribution of weedy cover between these 2 areas.

Habitat Use

From a qualitative standpoint, it appears that Attwater's prairie chickens require moderate-heavy cover of relatively high quality during the winter and spring months, as indicated by the high rankings that areas such as 2nd, and 3rd-year plus burns on loamy and sandy range sites received in the habitat selection analyses. These areas were also important for the nesting and early brooding periods. Beginning with the summer months through the fall, a wider variation in the types of habitats occurring in the highest ranked groups, indicate that a variety of habitat types can potentially meet the Attwater's requirements during this period. The correlations with habitat use also support this contention. Correlations for the December-February period indicated that use of a habitat varied significantly with its mean maximum grass height, maximum depth of down dead material, standing dead matter coverage (the dominant vegetation form during the winter period), overhead canopy obstruction, the coefficient of variation for bare ground cover, and inversely with insect abundance. All of these, with the possible exception of the latter 2, indicate that vegetative types with high cover values were used during this period. This is further supported by the negative correlation with bare ground cover which was significant at $\underline{P} < 0.08$.

During March-May, positive correlations for maximum forb and grass height, and for grass canopy cover also indicated that areas with moderate-heavy cover were used, although cover used was perhaps not quite as heavy as that required during the winter period, since the correlation with the depth of down dead material indicated no relationship during this period. Significant ($\underline{P} < 0.05$) correlations during this period were also observed with the coefficients of variation for grass cover, down dead cover, and bare ground cover (significant at $\underline{P} < 0.08$), indicating that habitat use was related to the relative homogeneity of the habitat with respect to these characteristics.

During the June-August period, the strongest correlation observed with habitat use for males and nonreproductive females was for that with insect availabilty, suggesting that perhaps insect availability played a role in habitat selection during this period. Although none of the correlations with brood habitat use were significant, perhaps due to small sample size, several investigators have pointed out the importance of insects to broods (e.g. Lehmann 1941, Yeatter 1943, Schwartz 1945, Jones 1963). Several of the nonreproductive birds used the same habitats as broods during this period.

Significant correlations were also observed for OV and maximum standing dead matter height during June-August, although correlations with grass or forb characteristics were not significant, suggesting that the type of cover was not all that important, as long as certain basic requirements were met during this period. None of the correlations were significant during the final quarter of the year except insect availability, which again suggests that a diversity of habitat types met the bird's requirements during this period. Cogar (1980) found that consumption of insects by Attwater's prairie chickens in Refugio County was greatest in the fall.

Examining the seasonal variation in the comparisons of use and availability of structural characteristics of the habitat, particularly for OV, depth of down dead matter, grass cover, down dead matter cover, and bare ground cover, provides more specific information on the season changes in habitat use by Attwater's prairie chickens. When available, habitats with mean OV values of 2 dm appeared to have been preferred throughout the year by males and nonreproductive females. However, seasonal changes were apparent in the selection of areas relative to other characteristics. For example, grass cover in the 26-50% range was used more than expected during winter and spring, while areas with the least grass cover were avoided. During summer and fall, areas with grass cover in the 26-50% range were either used in proportion to their availability or avoided. However, during fall, areas with grass cover in the 51-75% range were also used more than expected, suggesting that this period represents a transition period between summer and winter in terms of habitat requirements. Relative to coverage of down dead material, areas with 26-50% coverage were used more that expected during December-March, while during June-August these areas were avoided, and areas with 0% down dead material on the average were used more than expected. During September-November, down matter coverage classes were used in proportion to their availability. Average depths of down dead material in the 10-cm range were used more than expected during December-March, were avoided during June-August, and were used in proportion to their availability during the fall.

All of these observations suggest that grassland habitats with moderate cover are preferred during winter and spring, while more open habitat types are used during the summer. Fall appears to be a time of transition between summer and winter habitat requirements. Arthaud (1968) noted that agricultural areas met most of the summer requirements of male greater prairie chickens, except for roosting cover. Kessler (1978) observed heaviest use of native prairie tracts by Attwater's prairie chickens were during the cool months, and of fallow rice fields during the warm months. Results of this study agree with these observations.

Habitats used by broods also changed over time with respect to structural characteristics. Prior to 15 June, areas with OV values of 2 dm were used more than expected and areas with lower values avoided. After 15 June, areas with OV values in the 0.5-1-dm range were used preferentially, while those greater than that were used less than expected. Grass cover in the 26-50% range was preferred during the early brooding period, while that in the 6-25% range was preferred after 15 June. Habitats with bare ground coverage in the 26-50% range were used more than expected prior to 15 June. After that time broods used areas with ground cover in the 51-75% range, and avoided areas with less bare ground. Thus, good grass stands were used during the early brooding period, while much more open habitat such as that provided by 1st-year burns and coarse sand areas were used later.

Cogar et al. (1977) observed all Attwater's broods <5 weeks old in clumped midgrass cover, while older broods were observed more in artificially maintained areas associated with this cover type. Clumped midgrass was also the cover type in which 69% of the nests were found in that study. Schwartz (1945) indicated that broods spent their 1st few days in the vicinity of the nest, after which they moved toward nearby swales. At approximately 2 weeks of age, Schwartz observed that broods moved to higher areas and small grain fields. Arthaud (1968) observed broods <1 week old in good stands of native prairie with rough cover such as fence rows or rock outcrops nearby, while older broods were most frequently observed near prairie edges or fence rows, under small trees or shrubs, and in edges of cultivated fields. Viers (1967) noted that requirements for female greater prairie chickens in Kansas with broods were met by grassy ravines, while Briggs (1968), also working in Kansas, suggested that broods require moderate-heavy cover. Broods older than 4 weeks observed by Watt (1969) in Kansas were all near field borders, grain fields, or old fields. Lehmann (1941) observed that Attwater's broods used light cover areas in the vicinity of the nest until the young are 3-5 weeks old when extensive movements toward shade and water took place. Svedarsky (1979) noted that greater prairie chicken broods in Minnesota moved directly from undisturbed nesting cover to disturbed areas, with no differences being observed between early and late brood cover.

Thus, with few exceptions, most data suggest, as in this study, that habitat used early in the brooding period is generally different than that used later in the brooding period. As a result, unless habitats meeting all the requirements for brooding are highly interspersed, fairly extensive movements become necessary as observed by Lehmann (1941) and in this study during 1983. Lehmann (1941) and Christisen (1985) also pointed out the importance of diversity in grassland areas for prairie chicken management.

Although the components for good brood cover for both the early and later brooding periods were present on the refuge in 1st-year burns, fallow rice fields, coarse sand areas, and crop areas, in addition to the good quality grassland areas used for nesting and early brooding, the interspersion of these areas was generally poor. For example, during 1983 prior to the extensive movements made by the 3 broods in early June, 2 of the broods were located within 200-400 m of fallow rice and cropland areas which should have been acceptable brood habitat for the late summer period. Instead they moved over 1.6 km in the opposite direction before reaching suitable habitat. To correct this situation, individual burn sizes, averaging 86 ha since 1980, should be reduced while maintaining the same total area burned. Westemeier (1972) recommended burning tracts as large as 16 ha in a checkerboard pattern, with no more than half of the available cover being burned in a given year within 1.6 km of a booming ground. Westemeier also recommended employing burns of low enough intensity such that 20% of the residual cover would be left in a mosaic of unburned and closely burned patches. This goal could be accomplished by burning under relatively high humidity and low wind conditions such as during early morning or following a rain. However, care should be taken that all low lying areas are completely burned to discourage nesting in these areas. Similarly, Lehmann (1941) suggested that at least 40% of the grassy cover should be unburned each year, and should be distributed across the area in well drained patches of 2-16 ha. Lehmann (1941), Yeatter (1943), and Westemeier (1980) all noted that hens seemed to prefer to nest near an abrupt change in habitat such as an edge or trail. More such edge would be provided by a better interspersion of burned and unburned areas. Also, since no radioed broods used fallow rice fields most likely due to their poor distribution, it is recommended that these areas be converted back to native prairie as quickly as possible. In so doing, a substantial acreage of potential nesting habitat would be provided. Helicopter counts made by APCNWR have also indicated little use of fallow rice areas by broods in recent years (APCNWR, unpubl. data).

The average OV observed at nest sites of 2.3 dm is slightly higher than the average 2 dm which appears to have been preferred by males and nonreproductive females throughout the year. Cogar et al. (1977) suggested that clumped midgrass cover with an OV value of 2.5 dm offered the correct cover for Attwater's nests. Lutz (1979) and Lawrence (1982) observed mean OV values of 2.1 and 2.8 dm, respectively, at Attwater's nest sites. Buhnerkempe et al. (1984) observed a mean effective height of 2.9 dm at greater prairie chicken nest sites in Illinois.

Nesting data from this study indicate that burns should not occur more frequently than every 3 years, under the current grazing system, in order to maintain habitat with adequate residual cover for nesting. Kirsch et al. (1973) and Kirsch (1974) recommended burning on a 3-5 year interval in order to maintain cover of a sufficient density for nesting greater prairie chickens. Chamrad and Dodd (1972) noted that Attwater's nests were found in areas 1-2 years postburn in medium-dense vegetation.

However, the burning interval will be influenced to a great extent by grazing patterns and intensities. Data on cattle grazing collected in this study showed that 1st-year burns were grazed at higher intensities than all other major habitats except fallow rice, which was grazed at higher stocking densities from the outset. Qualitative observations on these 1st-year burns indicated that these areas were severely overgrazed, with grass species composition shifting toward early successional species such as Aristida spp. Observations indicated that these areas had not recovered even 2 years following the burn. Although periods of abnormally low rainfall occurred following the burns in 1984, management must be sufficiently flexible so as to prevent the abuse of grassland communities which occurred on these areas. Chamrad and Dodd (1972) also observed excessively short vegetation on postburn grazed areas. They recommended deferring burns throughout, or at least during the latter half of the postburn season. In any event, grazing should be regulated so that good quality nesting cover is available by approximately the 3rd growing season following the burn.

CONCLUSIONS/RECOMMENDATIONS

Based on data collected in this study in relation to data already present in the literature, the following conclusions and recommendations are made for improving the habitat of Attwater's prairie chickens on the Attwater Prairie Chicken National Wildlife Refuge:

(1) Given the diversity of habitat available which satisfy the summer and fall requirements for males and nonreproductive females, management should be focused on maintaining habitats required for winter cover, and for the critical nesting and brooding periods.

(a) High quality grassland areas, as typified by 2nd-year and older burns on loamy areas, were selected with the greatest intensity of all habitat types during winter and spring by males and nonreproductive females.

(b) Burned areas in their 3rd growing season and older were preferred by nesting hens.

(c) Cattle grazing should be regulated so that high quality nesting cover (i.e., clumped midgrass with OV values in the 2.5-dm range) will be available by approximately 3 growing seasons following burns. Therefore, grazing on 1st-year burns should be deferred at least during the last half of the 1st growing season.

(d) Areas used by broods prior to 15 June differed significantly from those used after that time. In general, good grassland stands as typified by 2nd-year and older burns on loamy and sandy areas were used early in the brooding period, while more open coarse sand and 1st-year burned areas were used during the latter part of the brooding period.

(e) Habitats satisfying all requirements for broods should be well interspersed. This can perhaps be achieved most easily by decreasing burn sizes to a maximum of 16 ha.

(f) To maintain maximum interspersion of habitat types and maximum area of potential nesting cover, large blocks of cultivated areas should be returned to native prairie as quickly as possible.

(g) No refuge operations causing significant disturbance, including those of tenant farmers, should be permitted in grassy or weedy areas during the period extending from 1 April-1 July to avoid destroying nests and broods. Cultivated areas should be prepared prior to that time. It is suggested that areas in food plots be rotated on a biennial basis between crops and weedy fallow areas. The fallow areas could be prepared the fall preceding planting, thereby leaving crops standing to provide winter food, and weedy fallow areas for broods the next spring.

(2) Data on predator abundance indicated no significant changes in abundance during the 3-year study period. Consideration of predator control is not recommended at this time until all other habitat improvements recommended have been implemented.

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Appendix A. Attwater's prairie chickens equipped with radio transmitters and/or banded during 1983-85 on Attwater Prairie Chicken National Wildlife Refuge.

Band	Sex	Age	Radio channel[a]	Capture date	Observations period			
					Days	N	Fate	Remarks
P-36558	M	ASY	01	11 Mar 83	9	2	Found dead	Unknown cause
P-36580	M	ASY	01	15 Apr 83	404	153	Found dead	Mammal. predation
P-61680	F	ASY	01	28 Feb 85	52	17	Killed on nest	Unknown
P-36596	M	ASY	01	25 Apr 85	99	43	Still on	End of study, Grn. 27/Yellow 45 band
P-36570	M	ASY	02	15 Mar 83	250	75	Unknown	Lost signal
P-36567	F	ASY	03	11 Mar 83	171	66	Unknown	Lost signal
P-36589	F	SY	03	25 Feb 84	116	48	Unknown	Radio came off
P-36578	F	SY	04	15 Mar 83	824	289	Found dead	Unknown cause
P-36583	M	ASY	05	2 May 83	27	16	Unknown	Lost signal
P-36573	F	ASY	05	15 Apr 84	44	20	Found dead	Avian predation
151	F	SY	05	15 Mar 85	140	58	Still on	End of study
P-36584	M	ASY	06	12 May 83	303	140	Found dead	Avian predation
P-61678	M	ASY	06	20 Feb 85	6	5	Found dead	Avian predation, Green 51 band
2	M	ASY	06	12 Mar 85	3	4	Unknown	Lost signal
P-36535	F	ASY	07	11 Mar 83	111	39	Unknown	Lost signal
P-36588	F	SY	07	15 Mar 84	69	22	Found dead	Mammal. predation
1	F	SY	07	12 Mar 85	24	11	Unknown	Lost signal
P-36582	M	ASY	08	2 May 83	63	31	Found dead	'Natural' causes
P-36591	F	SY	08	11 Mar 84	4	5	Found dead	Avian predation
P-61677	F	ASY	08	5 May 84	6	3	Found dead	Mammal. predation
P-61689	M	SY	08	16 Apr 85	2	3	Unknown	Lost signal, White 25 band
P-36538	F	ASY	09	11 Mar 83	118	46	Found dead	Mammal. predation
3	F	ASY	09	13 Mar 85	142	66	Still on	End of study
P-36592	F	ASY	10	11 Mar 84	23	11	Found dead	Mammal. predation
P-61687	F	SY	10	15 Mar 85	44	17	Found dead	Avian predation
P-36541	F	ASY	11	11 Mar 83	277	90	Unknown	Radio came off
P-36593	M	ASY	11	14 Apr 84	340	108	Unknown	Lost signal
P-61695	M	ASY	11	19 Apr 85	59	12	Found dead	'Natural' causes, Pink 25 band
101	F	ASY	11	3 May 85	28	14	Unknown	Lost signal
P-36548	F	ASY	13	11 Mar 83	81	34	Unknown	Lost signal
P-36586	M	ASY	13	2 Feb 84	67	16	Unknown	Radio came off
P-61694	M	SY	13	17 Apr 85	100	42	Unknown	Lost signal
P-36587	F	U	14	13 Mar 84	1	2	Found dead	Avian predation
P-61679	F	ASY	14	28 Feb 85	155	65	Still on	End of study
P-36590	F	SY	16	26 Feb 84	171	66	Unknown	Lost signal
P-61682	F	ASY	16	7 Mar 85	151	57	Still on	End of study
P-36557	F	SY	17	11 Mar 83	1	1	Found dead	Avian predation
P-36585	M	ASY	18	29 Jan 84	124	54	Unknown	Lost signal
P-36563	M	SY	19	15 Mar 83	116	39	Unknown	Lost signal

Band	Sex	Age	Radio channel[a]	Capture date	Observations period Days	N	Fate	Remarks
(continued)								
P-61688	F	SY	19	27 Mar 85	120	42	Unknown	Lost signal
P-61697	M	ASY	20	2 May 85	22	15	Unknown	Lost signal Blue 48 band
P-36595	F	SY	21	13 Mar 84	15	7	Found dead	Avian predation
P-36581	M	ASY	22	15 Apr 83	42	7	Unknown	Lost signal
P-61692	F	SY	22	17 Apr 85	5	3	Found dead	Avian predation
P-36596	F	SY	23	14 Mar 84	182	66	Found dead	Unknown cause
P-61681	F	ASY	23	7 Mar 84	1	1	Unknown	Lost signal
P-36597	F	SY	24	15 Mar 84	86	31	Found dead	Unknown cause
P-61698	F	SY	24	2 May 85	92	42	Still on	End of study
P-61676	M	ASY	24	20 Apr 84	141	35	Unknown	Lost signal
P-36579	M	ASY		15 Mar 83				Yellow 39 band
P-36594	M	ASY		13 Mar 84				Green 12 band
P-36598	M	ASY		14 Apr 84				Pink 1 band
P-36533	M	SY		15 Apr 84				Pink 2 band
P-61675	M	ASY		5 May 84				White 16 band
P-61683	M	ASY		7 Mar 85				Yellow 50 band
P-61684	M	ASY		12 Mar 85				Red 51 band
P-61686	F	SY		12 Mar 85				Pink 3 band, old injury
P-61690	M	SY		16 Apr 85				Red/white band
P-61691	M	SY		16 Apr 85				Yellow/white band
P-61693	M	ASY		17 Apr 85				Blue 28 band
P-61699	M	SY		2 May 85				Pink 7/Blue 14 band
P-61700	M	ASY		2 May 85				Yellow 44/Blue 12 band

[a]Radio frequencies were between 150.850-151.450 MHz.

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